U.S. Army Corps of Engineers
Omaha District

2008 Report

Water Quality Conditions in the Missouri River Mainstem System

September 2009

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2008 Report

Water Quality Conditions in the Missouri River Mainstem System

Prepared by:

Water Quality Unit
Water Control and Water Quality Section
Hydrologic Engineering Branch
Engineering Division
Omaha District
U.S. Army Corps of Engineers

September 2009

For Information Regarding This Document Please Contact:

U.S. Army Corps of Engineers, Omaha District
Attention: CENWO-ED-HA
1616 Capitol Avenue
Omaha, Nebraska 68102-4901
(402) 995-2310

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EXECUTIVE SUMMARY

Omaha District Water Quality Management Program

The Omaha District (District) of the U.S. Army Corps of Engineers (Corps) is implementing a Water Quality Management Program (WQMP) as part of the operation and maintenance activities associated with managing the Corps' civil works projects in the District. The WQMP addresses surface water quality management issues and adheres to the guidance and requirements specified in the Corps' Engineering Regulation – ER 1110-2-8154, "Water Quality and Environmental Management for Corps Civil Works Projects" (USACE, 1995).

A periodic report of water quality conditions in the Missouri River Mainstem System (Mainstem System) is prepared to document and assess water quality conditions occurring at the Corps' Mainstem System projects in the District. The report describes existing water quality conditions and identifies any evident surface water quality management concerns. The annual reporting of Mainstem System project water quality conditions is done to facilitate water quality management decisions regarding the operation and regulation of the Mainstem System projects.

General Water Quality Concerns in the Omaha District

The following general water quality concerns have been identified for civil works projects in the District: 1) reservoir eutrophication and hypolimnetic dissolved oxygen depletion, 2) sedimentation, 3) shoreline erosion, 4) bioaccumulation of contaminants in aquatic organisms, 5) occurrence of pesticides, and 6) urbanization.

Prioritization of District-Wide Water Quality Management Issues

The District has identified seven priority issues for water quality management; these priority issues and their relative ranking are listed in Table 1.2.

Summary of Project-Specific TMDL Considerations, Fish Consumption Advisories, and Other Water Quality Management Issues

Table 1.3 summarizes TMDL considerations, fish consumption advisories, and other water quality management issues applicable to the Mainstem System projects. The impaired uses and pollutant/stressors (i.e., TMDL considerations) and identified contamination (i.e., Fish Consumption Advisories) identified in Table 1.3 are taken directly from the latest State 303(d) impaired waters listings and issued fish consumption advisories. They are provided for information purposes and are not based on water quality monitoring conducted by the District. The listed other water quality management issues in Table 1.3 were identified by the District based on water quality monitoring and Corps water quality management concerns. Water quality management issues at specific Mainstem System projects will be assessed in further detail in Project Specific Reports (USACE, 2009a) that will be prepared for the project by the District.

Limnological Processes in Reservoirs

The Mainstem System projects in the District involve the operation and maintenance of reservoirs and the regulation of flows discharged from the reservoirs. Much of the water quality monitoring conducted by the District is done to determine existing water quality conditions and identify water quality

management concerns at these reservoirs. A basic understanding of the limnological processes that occur in reservoirs is needed to interpret the water quality information provided in this report. Chapter 2 of this report provides a basic overview of limnological processes that occur in reservoirs.

Water Quality Monitoring at the Mainstem System Reservoirs

Long-term, fixed-station ambient water quality monitoring has occurred at the six Mainstem System reservoirs (i.e., Fort Peck, Garrison, Oahe, Big Bend, Fort Randall, and Gavins Point) for the past 30 years. Recent ambient monitoring conducted by the District at the Mainstem System reservoirs included monthly (i.e., May through September) water quality monitoring at a near-dam, deepwater site. At Garrison, Fort Peck, and Oahe Reservoirs, additional long-term ambient sites were respectively added in 2006, 2007, and 2008. Water quality monitoring included field measurements and collection of depth-discrete water samples for laboratory analysis.

The District has monitored bacteria levels present at swimming beaches at the Gavins Point Project over the past 5 years. Five swimming beaches on Gavins Point Reservoir and one on Lake Yankton were monitored. Weekly grab samples were collected from May through September and analyzed for fecal coliform and *E. coli* bacteria.

Intensive water-quality surveys have recently been completed or are ongoing at all the Mainstem System projects. A 3-year intensive water-quality survey was completed at the Garrison Project in 2005, the Fort Peck Project in 2006, the Oahe Project in 2007, and the Fort Randall Project in 2008. Intensive surveys are currently ongoing at the Big Bend and Gavins Point Projects. The monitoring objectives of the intensive surveys are to collect water quality data to spatially describe water quality conditions present in the reservoirs during the late spring and summer, and to collect information to facilitate the application of the CE-QUAL-W2 hydrodynamic and water quality model.

Water Quality Monitoring at the Mainstem System Powerplants

As part of the operation of the Mainstem System powerplants, water is drawn from the intake structure of each dam and piped through the powerplant in a “raw water” supply line that is tapped for various uses. The “raw water” supply line is an open ended, flow-through system (i.e., water is continually discharged). A monitoring station, that measures water quality conditions of water drawn from near the start of the “raw water” supply line, has been irregularly maintained at each of the powerplants over the past several years. Recent water quality monitoring has consisted of year-round, hourly measurements of temperature and dissolved oxygen through the use of a data-logger. Monthly grab samples (year-round) have also been collected and analyzed. The water quality conditions measured in the “raw water” supply lines of the powerplants are believed to represent the water quality conditions present in the reservoirs near the dam intakes and in the tailwaters (i.e., Missouri River) immediately downstream of the dam.

Water Quality Monitoring of the Missouri River from Fort Randall Dam to Rulo, Nebraska

Since 2003, the District has cooperated with the Nebraska Department of Environmental Quality to monitor ambient water quality conditions along the Missouri River from Fort Randall Dam to Rulo, NE. Fixed-station monitoring has occurred at the following nine sites: Fort Randall Dam tailwaters; near Verdel, NE; Gavins Point Dam tailwaters; near Maskell, NE; near Ponca, NE; at Decatur, NE; at Omaha, NE; at Nebraska City, NE; and at Rulo, NE. Water quality monitoring consisted of taking field measurements and collecting near-surface grab samples monthly from October through March and biweekly from April through September. The collected grab samples were analyzed for various parameters.

Water Quality Monitoring at the Mainstem System Ancillary Lakes

Lake Yankton, Lake Pocasse, and Lake Audubon are ancillary lakes to the Mainstem System reservoirs respectively at the Gavins Point, Oahe, and Garrison Projects. Water quality monitoring at these three lakes has been irregular in the past. The District initiated ambient water quality monitoring at the lakes in 2006 as part of a 3-year rotational monitoring cycle. However, low-water conditions prevented boat access and therefore prevented water quality monitoring at Lake Pocasse. Monitoring included monthly sampling (May through September) at a near-dam deepwater location and included field measurements for depth profiling and water transparency and collection of near-surface and near-bottom water samples for laboratory analysis.

Water Quality Assessment Methods

For the purposes of this report, existing water quality is defined as water quality conditions that occurred during the past 5 years (i.e., 2004 through 2008). Water quality monitoring conducted during that period was used to describe existing water quality conditions.

Statistical analyses were performed on the water quality monitoring data collected at the Mainstem System reservoirs (including inflow and outflow sites), powerplants, on the Missouri River, and at the mainstem ancillary lakes. Descriptive statistics were calculated to describe central tendencies and the range of observations in existing water quality. Monitoring results were compared to applicable water quality standards criteria established by the appropriate States pursuant to the Federal Clean Water Act.

Longitudinal contour plots were constructed when adequate depth-profile measurements were collected along the length of a reservoir. Adequate information was collected in 2008 to construct longitudinal contour plots at all of the Mainstem System reservoirs. At these reservoirs longitudinal contour plots were constructed for water temperature, dissolved oxygen, and turbidity.

Longitudinal box plots were constructed when adequate measurements were collected along the length of a waterbody. Adequate information was collected to construct longitudinal box plots of existing water quality conditions all the Mainstem System reservoirs.

Depending on their bathymetry, lakes can experience thermally-induced density stratification in the summer. This can lead to significant vertical water quality variation if anoxic or near-anoxic conditions develop in the hypolimnion. Measured water temperature and dissolved oxygen depth profiles were plotted at the Mainstem System reservoirs and mainstem ancillary lakes. The plotted depth profiles were measured at a near-dam, deepwater ambient monitoring location. Depth profiles measured in the summer months over the past 5 years were plotted. The plots were reviewed to assess the occurrence of thermal stratification and hypolimnetic dissolved oxygen degradation.

The variation of selected parameters with depth was evaluated, where possible, by comparing near-surface and near-bottom collected samples collected at the Mainstem System reservoirs and ancillary lakes. The compared samples were collected at the near-dam, deepwater monitoring location over the past 5 years. The parameters compared included water temperature, dissolved oxygen, ORP, pH, alkalinity, and various nutrients.

Annual seasonal time series plots of water temperatures measured in the Missouri River immediately upstream and downstream of the Mainstem System reservoirs were constructed to display temporal variation. Time series plots were also prepared for water quality conditions monitored at the

Mainstem System powerplants during 2005 through 2008. Hourly water temperature, dissolved oxygen, and dam discharge were plotted semi-annually for the 4 years.

A lake Trophic State Index (TSI) was calculated from Secchi depth transparency, total phosphorus, and chlorophyll *a* measurements. Values for these three parameters were converted to an index number ranging from 0 to 100. This index value was used to determine the lake's trophic status in accordance with Table 4.1.

The phytoplankton community at the Mainstem System reservoirs was assessed based on collected grab samples. Laboratory analyses consisted of identification of phytoplankton taxa to the lowest practical level and quantification of taxa biovolume. These results were used to determine the relative abundance of phytoplankton taxa at the division level based on the measured biovolumes.

The impairment of beneficial uses designated in State water quality standards was evaluated by applying the impairment assessment criteria defined by the appropriate States.

Surface water quality trends at the Mainstem System reservoirs were assessed by evaluating water clarity (i.e. Secchi depth), total phosphorus, chlorophyll *a*, and trophic state index values from monitoring results obtained at long-term, fixed-station ambient monitoring sites for the period 1980 through 2008.

Water Quality Conditions Monitored at the Mainstem System Projects

Fort Peck

Monitoring of the existing water quality conditions of Fort Peck Reservoir indicated no significant water quality concerns. On a few occasions measured dissolved oxygen concentrations were below the water quality standards criterion of 5 mg/l. The measured low dissolved oxygen concentrations occurred in the hypolimnion near the reservoir bottom during the later part of the summer thermal stratification period. Water temperature, dissolved oxygen, and turbidity in Fort Peck Reservoir vary temporally, longitudinally from the dam to the reservoir's upper reaches, and vertically from the reservoir's surface to the bottom (Plates 7-19). During the summer, a thermocline typically becomes established in the reservoir at a depth of about 20 meters. Parameter that varied significantly from the surface to the bottom of the reservoir at the near-dam, deepwater location included water temperature, dissolved oxygen, ORP, pH, alkalinity, and total organic carbon. The dominant algal group sampled in the reservoir was Bacillariophyta (i.e., Diatoms). Over the past 29 years, Fort Peck Reservoir exhibited decreasing transparency and slightly increasing levels of total phosphorus and chlorophyll *a*. Monitoring indicated that the lacustrine zone of Fort Peck Reservoir has remained in a mesotrophic state.

Water quality monitoring of the existing conditions of the Fort Peck Dam discharge did not indicate any water quality standards attainment concerns. There appeared to be little correlation between dam discharge rates and measured water temperature and dissolved oxygen concentrations (Plates 31-56). Inflow temperatures of the Missouri River to Fort Peck Reservoir are generally warmer than the outflow temperatures of Fort Peck Dam during March through August and cooler than the outflow temperatures during September through February. A maximum temperature difference occurs in the summer when the Missouri River inflow temperature is about 10°C warmer than the Fort Peck Dam outflow temperature. Colder water temperatures and lower turbidity levels, attributed to the regulation of Fort Peck Dam, are believed to be impacting the endangered pallid sturgeon population in the Missouri River downstream of the dam.

Garrison

Monitoring of the existing water quality conditions of Garrison Reservoir indicated possible water quality concerns regarding water temperature and dissolved oxygen for the support of coldwater fishery habitat. Water temperatures in the epilimnion of the reservoir regularly exceed 15°C in the summer, while temperatures in the hypolimnion are less than 15°C. Dissolved oxygen levels in the hypolimnion continually degrade along the reservoir bottom as summer progresses, and can fall below 5.0 mg/l in late summer. Low dissolved oxygen conditions occur in the upstream reaches of the hypolimnion first and progress towards the dam. As the summer progresses, low dissolved oxygen conditions move up from the reservoir bottom into the mid- and upper reaches of the hypolimnion. This pinching off of coldwater habitat threatens the occurrence of coldwater fishery habitat in Garrison Reservoir, especially under low pool levels during drought conditions.

Water temperature, dissolved oxygen, and turbidity in Garrison Reservoir vary temporally, longitudinally from the dam to the reservoir's upstream reaches, and vertically from the reservoir's surface to the bottom (Plates 66-83). During the summer, a thermocline typically becomes established in the reservoir at a depth of about 25 meters. Parameters that significantly varied from the surface to the bottom of the reservoir at the near-dam, deepwater location included water temperature, dissolved oxygen, ORP, pH, alkalinity, total organic carbon, and total Kjeldahl nitrogen. The dominant algal group sampled in the reservoir was Bacillariophyta (i.e., Diatoms). Over the past 29 years, Garrison Reservoir exhibited slightly increasing concentrations of total phosphorus, and no observable trend in transparency and chlorophyll *a* levels. Monitoring indicated that the lacustrine zone of Garrison Reservoir is currently in a mesotrophic state and shows no observable trend of an increasing trophic state.

Water quality monitoring of the existing conditions of the Garrison Dam discharge did not indicate any significant water quality concerns. There is a significant correlation between dam discharge rates and measured water temperature and dissolved oxygen concentrations during the summer thermal stratification period of Garrison Reservoir (Plates 96-120). This indicates that the vertical extent of the withdrawal zone in the reservoir is dependent upon the discharge rate of the dam. This is believed to be a result of the design of the intake structure (i.e., bottom withdrawal) and the presence of the submerged intake channel leading to the intake structure. Water is likely drawn from an extended vertical zone in Garrison Reservoir year-round, but is only evident in the temperatures monitored at the powerhouse during reservoir thermal stratification during the summer. Inflow temperatures of the Missouri River to Garrison Reservoir are generally warmer than the outflow temperatures of Garrison Dam during April through September and cooler than the outflow temperatures during October through March. A maximum temperature difference occurs in the summer when the Missouri River inflow temperature is about 10°C warmer than the Garrison Dam outflow temperature.

As drought conditions persisted in early 2005, water levels in Garrison Reservoir had fallen to a record low pool elevation of 1805.8 ft-msl on May 12, 2005. At that time it was felt that, unless emergency water quality management measures were implemented in 2005 to preserve the coldwater habitat in the reservoir, the recreational sport fishery would likely be adversely impacted. The reduction of coldwater habitat is exacerbated by withdrawals through the Garrison Dam intake structure. Because the invert elevation of the intake portals to the Garrison Dam power tunnels (i.e., penstocks) is 2 feet above the reservoir bottom, water drawn through the penstocks comes largely from the lower depths of the reservoir. Thus, during the summer thermal-stratification period, water is largely drawn from the hypolimnetic volume of Garrison Reservoir. Three short-term water quality management measures were identified for implementation in 2005 in an effort to preserve the coldwater habitat in the reservoir. These measures, which were implemented at Garrison Dam, included: 1) application of a plywood barrier to the dam's intake trash racks, 2) utilization of head gates to restrict the opening to the dam's power tunnels, and 3) modification of the daily flow cycle and minimum flow releases from the dam. The three

implemented water quality management measures were targeted at drawing water into the dam from higher elevations within Garrison Reservoir. It is estimated the implementation of these short-term water quality management measures resulted in a potential saving of optimal coldwater habitat in Garrison Reservoir of about 379,390 acre-ft in 2005, about 1,021,150 acre-ft in 2006, 827,928 acre-ft in 2007, and about 794,850 acre-ft in 2008.

Oahe

Monitoring of the existing water quality conditions of Oahe Reservoir indicated possible water quality concerns regarding water temperature and dissolved oxygen for the support of Coldwater Permanent Fish Life Propagation. Water temperatures in the epilimnion of the reservoir regularly exceed the criterion of 18.3°C in the summer, while temperatures in the hypolimnion are less than 18.3°C. Dissolved oxygen levels in the hypolimnion continually degrade along the reservoir bottom as summer progresses and fall below the criterion of 7 mg/l in late summer. Dissolved oxygen levels did not fall below the criterion of 6 mg/l in the hypolimnion in the area of the reservoir near Oahe Dam. Dissolved oxygen concentrations regularly fall below 6 mg/l in the middle and upstream reaches of the hypolimnion. As the summer progresses, conditions of lower dissolved oxygen move up from the reservoir bottom into the lower reaches of the hypolimnion.

Water temperature, dissolved oxygen, and turbidity in Oahe Reservoir vary temporally, longitudinally from the dam to the reservoir's upstream reaches, and vertically from the reservoir's surface to the bottom (Plates 140-157). During the summer, a thermocline typically becomes established in the reservoir at a depth of about 20 meters. Parameter that significantly varied from the surface to the bottom of the reservoir at the near-dam, deepwater location included water temperature, dissolved oxygen, ORP, pH, and alkalinity. The dominant algal group sampled in the reservoir was Bacillariophyta (i.e., Diatoms). Over the past 29 years, Oahe Reservoir exhibited slightly increasing concentrations of total phosphorus and no observable trends in transparency or chlorophyll *a* levels. Monitoring indicated that the lacustrine zone of Oahe Reservoir is currently in a mesotrophic state and shows no observable trend of an increasing trophic state.

Water quality monitoring of the existing conditions of the Oahe Dam discharge indicated possible water quality concerns regarding temperature and dissolved oxygen for the support of Coldwater Permanent Fish Life Propagation. Temperatures of the water passed through Oahe Dam in the summer regularly exceeded the temperature criterion of 18.3°C. During the summer when Oahe Reservoir is thermally stratified, water temperatures in the epilimnion of the reservoir exceed 18.3°C, while temperatures in the hypolimnion are less than 18.3°C. Water discharged through Oahe Dam for power production is withdrawn from Oahe Reservoir at elevation 1525 ft-msl, approximately 110 feet above the reservoir bottom. Thus, water withdrawn from the reservoir in the summer comes largely from the epilimnion, especially when pool elevations are lower due to drought conditions. Because water passed through Oahe Dam during the summer is withdrawn from the epilimnion of the reservoir, the temperature criterion of 18.3°C for the Missouri River and Big Bend Reservoir just downstream of the dam are not being met during the summer when Oahe Reservoir is thermally stratified. Generally, dissolved oxygen levels were below 7 mg/l from mid July through September. Seemingly, the lower dissolved oxygen levels may be related to lower oxygen solubility with warmer water and possible oxygen degradation in the hypolimnion during late summer.

There appeared to be little correlation between dam discharge rates and measured water temperature and dissolved oxygen concentrations (Plates 171 - 190). Inflow temperatures of the Missouri River to Oahe Reservoir are generally warmer than the outflow temperatures of the Oahe Dam discharge during the period of April through June. Outflow temperatures of the Oahe Dam discharge are generally

warmer than the inflow temperatures of the Missouri River during the period of July through March. A maximum temperature difference occurs in the fall when the Oahe Dam discharge temperature is about 4°C warmer than the Missouri River inflow temperature.

Big Bend

Water quality monitoring of the existing conditions of Big Bend Reservoir indicated possible water quality concerns regarding water temperature and dissolved oxygen for the support of Coldwater Permanent Fish Life Propagation. Based on the criteria for the protection of Coldwater Permanent Fish Life propagation, 62 percent of the observations exceeded water temperature criteria and 4 to 16 percent of the observations did not meet dissolved oxygen criteria. Ambient summer water temperatures in Big Bend Reservoir do not appear to be cold enough to support coldwater permanent fish life propagation as defined by State water quality criteria. Consideration should be given to reclassify the reservoir for a warmwater permanent fish life propagation use based on a use attainability assessment of "natural conditions" regarding ambient water temperatures.

Big Bend Reservoir exhibits limited summer thermal stratification due to its shallower depth and the high discharge rates that occur through Big Bend Dam; however, temperature and dissolved oxygen can vary significantly during periods of stratification (Plates 200-209). Significant longitudinal variation in turbidity levels occurs on Big Bend Reservoir, especially following period of significant inflows from the Bad River (Plates 210-213). Parameters that significantly varied from the surface to the bottom of the reservoir at the near-dam, deepwater location included water temperature, dissolved oxygen, ORP, and pH. The dominant algal group sampled in the reservoir was Bacillariophyta (i.e., Diatoms). Over the past 29 years, Big Bend Reservoir exhibited slightly increasing concentrations of total phosphorus and decreasing levels of transparency and chlorophyll *a*. Monitoring indicated that the lacustrine zone of Big Bend Reservoir is currently in a mesotrophic to moderately eutrophic state and shows a slightly increasing trend in trophic state.

Monitoring of the existing water quality conditions of the Big Bend Dam discharge did not indicate any water quality concerns. There appeared to be only minor correlation between dam discharge rates and measured water temperature and dissolved oxygen concentrations (Plates 226-245). Inflow temperatures of the Missouri River to Big Bend Reservoir are about 2°C warmer than the outflow temperatures of Big Bend Dam during the winter. Temperatures of the Big Bend Dam discharge are about 1-2°C warmer than the inflow temperatures of the Missouri River during the spring, summer, and fall.

Fort Randall

Monitoring of the existing water quality conditions of Fort Randall Reservoir indicated possible water quality concerns regarding suspended solids for the support of Warmwater Permanent Fish Life Propagation. The chronic suspended solids criterion was exceeded in Fort Randall Reservoir in the area near the confluence of the White River.

Water temperature, dissolved oxygen, and turbidity in Fort Randall Reservoir vary temporally, longitudinally from the dam to the reservoir's upstream reaches, and vertically from the reservoir's surface to the bottom (Plates 257-270). During the summer, a thermocline typically becomes established in the reservoir at a depth of about 25 meters. Parameters that significantly varied from the surface to the bottom of the reservoir at the near-dam, deepwater location included water temperature, dissolved oxygen, ORP, pH, total organic carbon, and total Kjeldahl nitrogen. The dominant algal group sampled in the reservoir was Bacillariophyta (i.e., Diatoms). Over the past 29 years, Fort Randall Reservoir exhibited decreasing levels of transparency and chlorophyll *a* and no observable trend in total

phosphorus. Monitoring indicated that the near-dam lacustrine zone of Fort Randall Reservoir is currently in a mesotrophic state and shows no observable trend of a changing trophic state.

Water quality monitoring of the existing conditions of the Fort Randall Dam discharge indicated no water quality concerns. There is a significant correlation between dam discharge rates and measured water temperature and dissolved oxygen concentrations during the summer thermal stratification period of Fort Randall Reservoir (Plates 283-301). This indicates that the vertical extent of the withdrawal zone in the reservoir is dependent upon the discharge rate of the dam. This is believed to be a result of the design of the intake structure (i.e., bottom withdrawal) and the presence of the submerged approach channel leading to the intake structure. Water is likely drawn from an extended vertical zone in Fort Randall Reservoir year-round, but is only evident in the temperatures monitored at the powerhouse during reservoir thermal stratification during the summer.

Inflow temperatures of the Missouri River to Fort Randall tend to be at little warmer than the outflow temperatures of Fort Randall Dam during the spring and early summer. Outflow temperatures of the Fort Randall Dam discharge tend to be a little warmer than the Missouri River inflow temperatures in the late-summer and fall.

Gavins Point

Water quality monitoring of the existing conditions of Gavins Point Reservoir indicated a possible water quality concern regarding dissolved oxygen for the support of warmwater aquatic life and nutrients for aesthetics. Based on the criteria for the protection of warmwater aquatic life, 8 percent of the near-dam observations did not meet dissolved oxygen criteria. The dissolved oxygen measurements that were below the 5 mg/l criterion occurred near the reservoir bottom in the hypolimnion during the summer on occasions when the reservoir was thermally stratified. Monitored levels of chlorophyll *a*, total nitrogen, and total phosphorus exceed impairment criteria (i.e., 303(d) criteria for listing a waterbody as impaired) identified by the State of Nebraska for the protection of aesthetics.

During periods of calm weather in the summer, Gavins Point Reservoir will develop a slight thermal stratification. When this slight stratification occurs, a thermocline is present at about 8 meters depth. This indicates the reservoir is probably polymixic. The thermal stratification breaks down under windier conditions, given the shallow depth of the reservoir (i.e., 14 meters), and the reservoir mixes throughout its water column. Parameters that significantly varied from the surface to the bottom of the reservoir at the near-dam, deepwater location included water temperature, dissolved oxygen, ORP, and pH. The dominant algal group sampled in the reservoir was Bacillariophyta (i.e., Diatoms). Over the past 29 years, Gavins Point Reservoir exhibited slightly increasing concentrations of total phosphorus and decreasing levels of transparency and chlorophyll *a*. Monitoring indicated that the lacustrine zone of Gavins Point Reservoir is currently in a eutrophic state and shows a slight increasing trend in trophic state.

Water quality monitoring of the existing conditions of the Gavins Point Dam discharge did not indicate any water quality concerns. There appeared to be little correlation between dam discharge rates and measured water temperature and dissolved oxygen concentrations (Plates 347-366). Inflow temperatures of the Missouri River to Gavins Point Reservoir tend to be at little cooler than the outflow temperatures of Gavins Point Dam during the spring and early summer. Outflow temperatures of the Gavins Point Dam discharge tend to be a little warmer than the Missouri River inflow temperatures in the late-summer and fall.

Comparison of Water Quality Conditions at the Mainstem Reservoirs

A comparison of existing water quality conditions monitored at the Mainstem System reservoirs is provided in Tables 5.23 and 5.24.

Lower Missouri River

Monitoring of the existing water quality conditions of the lower Missouri River from Gavins Point Dam to Rulo, Nebraska indicated no water quality concerns. Longitudinal variation in selected water quality parameters was assessed with box plots arranged relative to their respective locations along the Missouri River (Plate 381). Parameters that exhibited no observable longitudinal trend included pH, specific conductance, and total ammonia. Parameters that slightly decreased in a downstream direction included dissolved oxygen. Parameters that slightly increased in a downstream direction included water temperature, chloride, chemical oxygen demand, total organic carbon, total Kjeldahl nitrogen, atrazine, and metolachlor. Parameters that greatly increased in downstream direction included turbidity, total suspended solids, nitrate-nitrite nitrogen, and total phosphorus.

Existing Nutrient Concentrations and Loadings along the Missouri River from Montana to Nebraska

A box plot of nitrate-nitrite nitrogen, total nitrogen, and total phosphorus concentrations monitored along the Missouri River from near Landusky, Montana to Rulo, Nebraska over the 5-year period 2004 through 2008 is provided in Figure 6.4. A bar chart of estimated mean daily loads of the same nutrients based on calculated flux rates over the 5-year period is provided in Figure 6.5.

Mainstem Ancillary Lakes

Monitoring of existing water quality conditions at Lakes Audubon and Yankton indicated no major water quality concerns.

<u>Water Quality Monitoring and Management Activities Planned for Future Years</u>

A tentative schedule of water quality monitoring targeted for implementation over the next 5 years at the Mainstem System Projects is given in Table 8.1. The identified data collection activities are considered the minimum needed to allow for the annual assessment of water quality conditions at District projects, and the preparation of project-specific water quality reports and water quality management objectives for the Mainstem System Projects. The actual monitoring activities that are implemented will be dependent upon the availability of future resources.

The CE-QUAL-W2 hydrodynamic and water quality model is being applied to facilitate the development project-specific water quality reports and project-specific water quality management objectives. The tentative schedule for implementing these water-quality management planning activities at the Mainstem System Projects is given in Table 8.2.

1 INTRODUCTION

1.1 OMAHA DISTRICT WATER QUALITY MANAGEMENT PROGRAM

The Omaha District (District) of the U.S. Army Corps of Engineers (Corps) is implementing a Water Quality Management Program (WQMP) as part of the operation and maintenance activities associated with managing the Corps' civil works projects in the District. The WQMP addresses surface water quality management issues and adheres to the guidance and requirements specified in the Corps' Engineering Regulation – ER 1110-2-8154, "Water Quality and Environmental Management for Corps Civil Works Projects" (USACE, 1995). The following four goals have been established for the District's WQMP (USACE, 2009a):

1) Ensure that surface water quality, as affected by District projects and their regulation, is suitable for project purposes, existing water uses, and public health and safety, and is in compliance with applicable Federal, Tribal, and State water quality standards.
2) Establish and maintain a surface water quality monitoring and data evaluation program that facilitates the achievement of water quality management objectives, allows for the characterization of water quality conditions, and defines the influence of District Projects on surface water quality.
3) Establish and maintain strong working partnerships and collaboration with appropriate entities within and outside the Corps regarding surface water quality management at District Projects.
4) Document the water quality management activities of the District's Water Quality Management Program and surface water quality conditions at District Projects to record trends, identify problems and accomplishments, and provide guidance to program and project managers.

Water quality data collection and assessment are of paramount importance to the implementation of the District's WQMP.

The reporting of water quality conditions is done to document and assess water quality conditions occurring at Corps civil works projects in the District. This report describes existing and historic water quality conditions and identifies any evident surface water quality management issues. The reporting of water quality conditions is done to facilitate water quality management decisions regarding the operation and regulation of Corps projects.

1.2 CORPS CIVIL WORKS PROJECTS WITHIN THE OMAHA DISTRICT

The location of Corps' Missouri River Mainstem System (Mainstem System) civil works project areas within the District and background information on the projects are provided in Figure 1.1 and Table 1.1. These are the Mainstem System civil works projects under the purview of the District's WQMP.

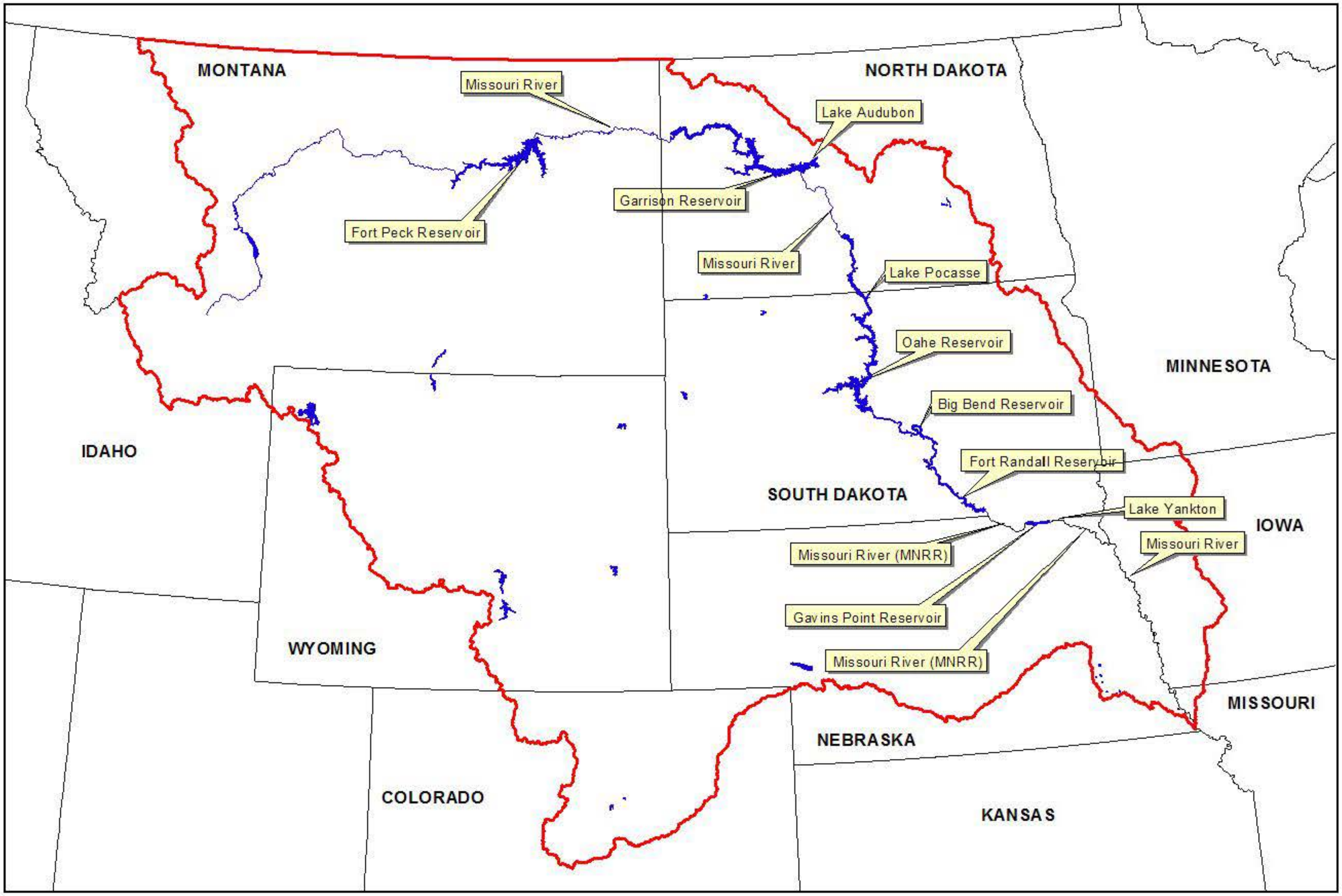

Figure 1.1. Missouri River Mainstem System civil works projects in the Omaha District. (Refer to Table 1.1 for project information.)

Table 1.1. Background information for Corps Missouri River Mainstem System project areas located in the Omaha District.

Project Area	Location	Dam Closure	Lake Size or River Length(1)	Authorized Proposes(2)	Water Quality Designated Beneficial Uses(3)
MAINSTEM RESERVOIRS					
Fort Peck (Fort Peck Lake)	Fort Peck, MT	1937	246,000 A (mp)	FC, Rec, FW, HP, WS, WQ, Nav, Irrig(4)	Rec, FW, WAL, DWS, IWS, AWS
Garrison (Lake Sakakawea)	Garrison, ND	1953	380,000 A (mp)	FC, Rec, FW, HP, WS, WQ, Nav, Irrig(5)	Rec, FW, CAL, DWS, IWS, AWS
Oahe (Lake Oahe)	Pierre, SD	1958	374,000 A (mp)	FC, Rec, FW, HP, WS, WQ, Nav, Irrig(4)	Rec, FW, CAL, DWS, IWS, AWS
Big Bend (Lake Sharpe)	Chamberlain, SD	1963	61,000 A (mp)	FC, Rec, FW, HP, WS, WQ, Nav, Irrig(4)	Rec, FW, CAL, DWS, IWS, AWS
Fort Randall (Lake Francis Case)	Pickstown, SD	1952	102,000 A (mp)	FC, Rec, FW, HP, WS, WQ, Nav, Irrig(4)	Rec, FW, WAL, DWS, IWS, AWS
Gavins Point (Lewis and Clark Lake)	Yankton, SD	1955	31,000 A (mp)	FC, Rec, FW, HP, WS, WQ, Nav, Irrig(4)	Rec, FW, WAL, DWS, IWS, AWS, Aes
MAINSTEM RESERVOIR ANCILLARY LAKES					
Lake Audubon (Garrison Project – Snake Creek Dam)	Garrison, ND	1952	18,780 A (mp)	Rec, FW	Rec, FW, WAL, DWS, IWS, AWS
Lake Pocasse (Oahe Project – Spring Creek Dam)	Pollock, SD	1961	1,545 A (mp)	FW	Rec, FW, WAL, AWS
Lake Yankton (Gavins Point Project)	Yankton, SD	1955	250 A	Rec, FW	Rec, WAL, AWS, Aes
MISSOURI RIVER					
Fort Peck Reach	Fort Peck Dam to Garrison Reservoir	-----	204 M	-----	Rec, FW, CAL, WAL, DWS, IWS, AWS
Garrison Reach	Garrison Dam to Oahe Reservoir	-----	87 M	-----	Rec, FW, WAL, DWS, IWS, AWS
Oahe Reach	Oahe Dam to Big Bend Reservoir	-----	5 M	-----	Rec, FW, CAL, DWS, IWS, AWS
Fort Randall Reach	Fort Randall Dam to Gavins Point Reservoir	-----	39 M	National Recreational River(6)	Rec, FW, WAL, DWS, IWS, AWS, Aes, OSRW
Gavins Point Reach	Gavins Point Dam to Ponca, NE	-----	59 M	National Recreational River(6)	Rec, FW, WAL, DWS, IWS, AWS, Aes, OSRW
Kensler's Bend Reach	Ponca, NE to Sioux City, IA	-----	17 M	-----	Rec, FW, WAL, DWS, IWS, AWS, Aes, OSRW
Lower Missouri River Reach	Sioux City, IA to Rulo, NE	-----	237 M	BS, Nav	Rec, FW, WAL, DWS, IWS, AWS, Aes

(1) A = acres, M = miles, mp = top of multipurpose pool, cp = top of conservation pool.

(2) Purposes authorized under Federal laws for the operation of the Corps projects.

FC = Flood Control, Rec = Recreation, FW = Fish & Wildlife, HP = Hydroelectric Power, WS = Water Supply, WQ = Water Quality, Nav = Navigation, Irrig = Irrigation, BS = Bank Stabilization.

(3) Water quality dependent beneficial uses designated to the waterbody in State water quality standards pursuant to the Federal Clean Water Act.

Rec = Recreation, FW = Fish and Wildlife, WAL, Warmwater Aquatic Life, CAL = Coldwater Aquatic Life, DWS = Domestic Water Supply, IWS = Industrial Water Supply, AWS = Agricultural Water Supply, Aes = Aesthetics, OSRW = Outstanding State Resource Water.

(4) Section 8 (PL 78-534) Federal irrigation has not been developed at this project; however, water is being withdrawn for private irrigation use.

(5) There is a Section 8 Federal irrigation project authorized at this project, but it is not yet operational; however, water is being withdrawn for private irrigation use.

(6) Designated a Recreational River under the Federal Wild and Scenic Rivers Act.

1.3 WATER QUALITY MONITORING GOALS AND OBJECTIVES

The District has established purposes and monitoring objectives for surface water quality monitoring under its WQMP. These monitoring purposes and objectives were established to meet the water quality information needs of the WQMP and the water quality management objectives, data collection rules and objectives, data application guidance, and reporting requirements identified in ER 1110-2-8154. Pertinent monitoring goals and objectives that have been established are:

<u>Purpose 1: Determine surface water quality conditions at District Projects</u>.

Monitoring Objectives:

- For new District water resource projects, establish baseline surface water quality conditions as soon as possible and appropriate.
- Characterize the spatial and temporal distribution of surface water quality conditions at District Projects.
- Identify pollutants and their sources that are affecting surface water quality and the aquatic environment at District Projects.
- Evaluate water/sediment interactions and their effects on overall surface water quality at District Projects.
- Identify the presence and concentrations of contaminants in indicator and human-consumed fish species at District Projects.
- Investigate, as necessary, unique events (e.g., fish kills, hazardous waste spills, operational emergencies, health emergencies, public complaints, etc.) at District Projects that may have degraded surface water quality or indicate the aquatic environment has been impacted.

<u>Purpose 2: Document surface water quality concerns that are due to the operation and reservoir regulation of District Projects</u>.

Monitoring Objectives:

- Determine if surface water quality conditions at District Projects or attributable to District operations or reservoir regulation (i.e., downstream conditions resulting from reservoir discharges) meets applicable Federal, Tribal, and State water quality standards.
- Determine if surface water quality conditions at District Projects or attributable to District operations or reservoir regulation are improving, degrading, or staying the same over time.
- Apply water quality models to assess surface water quality conditions at District Projects.

<u>Purpose 3: Provide data to support Project operations and reservoir regulation for effective management and enhancement of surface water quality and the aquatic environment</u>.

Monitoring Objectives:

- Provide surface water quality data required for real-time regulation of District Projects.
- Collect the information needed to design, engineer, and implement measures or modifications at District Projects to enhance surface water quality and the aquatic environment.

<u>Purpose 4: Evaluate the effectiveness of structural or regulation measures implemented at District Projects to enhance surface water quality and the aquatic environment</u>.

Monitoring Objectives:

- Evaluate the effectiveness of implemented measures at District Projects to improve surface water quality and the aquatic environment.

1.4 DATA COLLECTION APPROACHES

Several data collection approaches have been identified by the District for collecting surface water quality data. Pertinent water quality monitoring approaches are:

- Long-term, fixed-station ambient monitoring;
- Intensive surveys;
- Special studies; and
- Investigative monitoring.

Long-term, fixed-station ambient monitoring is intended to provide information that will allow the District to determine the status and trends of surface water quality at District Projects. This type of sampling consists of systematically collecting samples at the same location over a long period of time (e.g., collecting monthly water samples at the same site for several years).

Intensive surveys are intended to provide more detailed information regarding surface water quality conditions at District Projects. They typically will include more sites sampled over a shorter timeframe than long-term fixed-station monitoring. Intensive surveys will provide the detailed water quality information needed to thoroughly understand surface water quality conditions at a project.

Special studies are conducted to address specific information needs. Special water quality studies may be undertaken to collect the information needed to "scope-out" a specific water quality problem, apply water quality models, design and engineer modifications at projects, or evaluate the effectiveness of implemented water quality management measures.

Investigative monitoring is typically initiated in response to an immediate need for surface water quality information at a District Project. This may be in response to an operational situation, the occurrence of a significant pollution event, public complaint, or a report of a fish kill. Any District response to a pollution event or fish kill would need to be coordinated with the appropriate Tribal, State, and Local agencies. The type of sampling that is done for investigative purposes is highly specific to the situation under investigation.

1.5 GENERAL WATER QUALITY CONCERNS IN THE OMAHA DISTRICT

1.5.1 RESERVOIR EUTROPHICATION AND HYPOLIMNETIC DISSOLVED OXYGEN DEPLETION

Reservoirs are commonly classified or grouped by trophic or nutrient status. The natural progression of reservoirs through time is from an oligotrophic (i.e., low nutrient/low productivity) through a mesotrophic (i.e., intermediate nutrient/intermediate productivity) to a eutrophic (i.e., high nutrient/high productivity) condition. The tendency toward the eutrophic or nutrient-rich status is common to all impounded waters. The eutrophication, or enrichment process, can be accelerated by nutrient additions to the reservoir resulting from cultural activities.

As deeper, temperate lakes warm in the spring and summer they typically become thermally stratified, due to the density differences of the water, into three vertical zones: 1) epilimnion, 2) metalimnion, and 3) hypolimnion. The epilimnion is the upper zone of less dense, warmer water in the lake that remains relatively mixed due to wind action and convection. The metalimnion is the middle zone that represents the transition from warm surface water to cooler bottom water. The hypolimnion is the bottom zone of more dense, colder water that is relatively quiescent.

A significant water quality concern that can occur in reservoirs that thermally stratify in the summer is the depletion of dissolved oxygen levels in the hypolimnion. The depletion of dissolved oxygen is attributed to the differing density of water with temperature, the utilization of dissolved oxygen in the decomposition of organic matter, and the oxidation of reduced inorganic substances. When density differences become significant, the deeper colder water is isolated from the surface and re-oxygenation from the atmosphere. In eutrophic lakes, the decomposition of the abundant organic matter can significantly reduce dissolved oxygen in the quiescent hypolimnetic zone. Anoxic conditions in the hypolimnion can result in the release of sediment-bound substances (e.g., phosphorus, metals, sulfides, etc.) as the reduced conditions intensify and result in the production of toxic and caustic substances (e.g., hydrogen sulfide, etc.). Most fish and other intolerant aquatic life cannot inhabit water with less than 4 to 5 mg/l dissolved oxygen for extended periods. These conditions can impact aquatic life in the reservoir and also in waters downstream of the reservoir if its releases are from a bottom outlet.

1.5.2 SEDIMENTATION

Sedimentation is a process that reduces the usefulness of reservoirs. In the design and construction of reservoirs, the Corps will commonly allow for additional volume to accommodate sedimentation. The incoming sediment can seriously affect the reservoir ecology, fisheries, and benthic aquatic life. The reservoir can suffer ecological damage before a volume function such as flood control is impacted. The influx of sediment eliminates fish habitat, adds nutrients, destroys aesthetics, and decreases biodiversity. Working closely with the project sponsors in an effort to manage sediment input could ultimately prolong reservoir life. Wetlands or sediment traps could be constructed at the headwaters of a reservoir, either upstream of the reservoir or in a portion of the reservoir's upper end, to trap sediment.

1.5.3 SHORELINE EROSION

Shoreline erosion is a major problem occurring on nearly all reservoirs located in areas of erodible soils such as the Midwest. Over 6,000 miles of reservoir shoreline exist at District Projects, and it is estimated that over 70 percent of this shoreline is eroding. Some locations have been protected, such as recreational and archaeological sites, but most of the shoreline continues to erode. Continued loss of the shoreline habitat (littoral zone) results in the loss of fishery habitat as well as loss of habitat for other biota such as aquatic vegetation and benthic invertebrates.

1.5.4 BIOACCUMULATION OF CONTAMINANTS IN AQUATIC ORGANISMS

Bioaccumulation is the accumulation of contaminants in the tissue of organisms through any route, including respiration, ingestion, or direct contact with contaminated water or sediment. Bioavailable, for chemicals, is the state of being potentially available for biological uptake by an aquatic organism when that organism is processing or encountering a given environmental medium (e.g., the chemicals that can be extracted by the gills from the water as it passes through the respiratory cavity or the chemicals that are absorbed by internal membranes as the organism moves through or ingests sediment). In the aquatic environment, a chemical can exist in three different basic forms that affect availability to organisms: 1) dissolved, 2) sorbed to biotic or abiotic components and suspended in the water column or deposited on the bottom, and 3) incorporated (accumulated) into organisms. Bioconcentration is a process by which there is a net accumulation of a chemical directly from water into aquatic organisms resulting from simultaneous uptake (e.g., by gill or epithelial tissue) and elimination. Biomagnification is the result of the process of bioconcentration and bioaccumulation by which tissue concentrations of bioaccumulated chemicals increase as the chemical passes up through two or more trophic levels. The term implies an efficient transfer of a chemical from food to consumer so that residual concentrations increase systematically from one trophic level to the next.

Bioaccumulation of contaminants can have a direct effect on aquatic organisms. These effects can be chronic (reduced growth, fecundity, etc.) and acute (lethality). The bioaccumulation of contaminants can also be a concern to human health when the contaminated tissue of aquatic organisms is consumed by humans.

1.5.5 OCCURRENCE OF PESTICIDES

Pesticides are widely applied to lands throughout the District. Pesticides detected at District Projects over the past 5 years include: acetochlor, alachlor, atrazine, deethylatrazine, deisopropylatrazine, metolachlor, metribuzin, prometon, and propazine. Many of these pesticides do not have State or Federal numeric water quality criteria established.

1.5.6 URBANIZATION

Construction methods used to develop urban areas disturb the land and allow sediment-laden runoff to impact nearby streams and lakes. Best management practices (BMPs) to minimize construction-associated sedimentation damages are used ineffectively in many cases. BMPs to control the impact of construction practices include; sediment retention basins, phased "grading", and runoff control (e.g. hay bales, silt fences, vegetative ground cover, terracing, etc). Efforts need to be made to prevent sedimentation from off-project construction activities from causing impacts to District Projects. This could be accomplished by the appropriate State, County, or City agencies working with developers.

Post-construction problems are commonly associated with storm drainage and urban pollution. The conversion of grasslands or forests to roads, rooftops, sidewalks, and other water impervious surfaces make stream flows more variable and increase the frequency of high flow events. In addition, pollutants associated with urban drainage can impact downstream waterbodies. Storm sewer exits can be allowed on Project lands provided detention in the form of ponds, swales, or wetlands exist on private property. A developer may be asked to construct a series of wetlands to slow downhill flows and provide time for bacterial die-off, chemical degradation, reduced flow rates, and sediment settling.

1.6 PRIORITIZATION OF DISTRICT-WIDE WATER QUALITY MANAGEMENT ISSUES

The District has identified seven priority issues for water quality management. These priority issues and their relative ranking are listed in Table 1.2.

Table 1.2. Priority water quality management issues within the Omaha District**.**

Ranking*	Water Quality Management Issue
1	Determine how regulation of the Missouri River Mainstem System (Mainstem System) dams affects water quality in the impounded reservoir and downstream river. Utilize the CE-QUAL-W2 hydrodynamic and water quality model to facilitate this effort.
2	Evaluate how eutrophication is progressing in the Mainstem System reservoirs, especially regarding the expansion of anoxic conditions in the hypolimnion during summer stratification.
3	Determine how flow regimes, especially the release of water from Mainstem System projects, affects water quality in the Missouri River.
4	Provide water quality information to support Corps reservoir regulation elements for effective surface water quality and aquatic habitat management.
5	Provide water quality information and technical support to the Tribes and States in the development of their Section 303(d) lists and development and implementation of TMDLs at District Projects.
6	Identify existing and potential surface water quality problems at District Projects and develop and implement appropriate solutions.
7	Evaluate surface water quality conditions and trends at District Projects.

* 1 = Highest priority, 7 = Lowest Priority

1.7 PROJECT-SPECIFIC WATER QUALITY MANAGEMENT ISSUES AT THE MAINSTEM SYSTEM PROJECTS

1.7.1 SECTION 303(D) LISTINGS OF IMPAIRED WATERS

Under Section 303(d) of the Federal Clean Water Act (CWA), Tribes and States, with the delegated authority from the U.S. Environmental Protection Agency (EPA), are required to prepare a

periodic list of impaired waters [i.e., Section 303(d) list]. Impaired waters refer to those waterbodies where it has been determined that technology-based effluent limitations required by Section 301 of the CWA are not stringent enough to attain and maintain applicable water quality standards. Tribes and States, as appropriate, are required to establish and implement Total Maximum Daily Loads (TMDLs) for waterbodies on their Section 303(d) lists.

1.7.2 FISH CONSUMPTION ADVISORIES

Fish are capable of accumulating many toxic substances in excess of 1,000 times the concentrations found in surface waters. The public has expressed concerns on whether fish caught from District Project waters are safe to consume. It is important that answers to public health concerns be based on substantiated knowledge of toxicants in fish fillets and the public health risks associated with measured toxicant concentrations. This type of information can be used by States when considering the issuance of fish consumption advisories. Fish consumption advisories have been issued for fish caught from certain District Project waters. Mercury is the most prevalent contaminant leading to the issuance of fish consumption advisories in the District.

1.7.3 SUMMARY OF PROJECT-SPECIFIC TMDL CONSIDERATIONS, FISH CONSUMPTION ADVISORIES, AND OTHER WATER QUALITY MANAGEMENT ISSUES

Table 1.3 summarizes TMDL considerations, fish consumption advisories, and other water quality management issues applicable to the Mainstem System Projects. The impaired uses and pollutant/stressors (i.e., TMDL considerations) and identified contamination (i.e., Fish Consumption Advisories) identified in Table 1.3 are taken directly from the appropriate State 303(d) impaired waters listings and issued fish consumption advisories. They are provided for information purposes and are not based on water quality monitoring conducted by the District. The listed other water quality management issues in Table 1.3 were identified by the District based on water quality monitoring and Corps water quality management concerns. Water quality management issues at specific Mainstem System Projects will be assessed in detail in Project-Specific Reports (USACE, 2009a) prepared for the Project by the District.

Table 1.3. Summary of site-specific water quality management issues and concerns for the Missouri River Mainstem System in the Omaha District.

Project Area	TMDL Considerations*				Fish Consumption Advisories		Other Water Quality Management Issues
	On 303(d) List	Impaired Uses	Pollutant/Stressor	TMDL Completed	Advisory in Effect	Identified Contamination	
Missouri River (Bullwhacker Creek to Fort Peck Reservoir)	Yes	Aquatic Life Drinking Water Supply Warmwater Fishery	Riparian Alteration (AL, WWF) Arsenic (AL, DWS, WWF) Copper (AL, WWF)	No	No	-----	Pallid sturgeon recovery priority area
Fort Peck Reservoir	Yes	Drinking Water Supply Recreation	Lead, Mercury Aquatic Plants – Native	No	Yes	Mercury	-----
Missouri River (Fort Peck Dam to the Milk River)	Yes	Aquatic Life Coldwater Fishery	Riparian Alteration Flow Alteration Water Temperature	No	No	-----	Pallid sturgeon recovery priority area
Missouri River (Milk River to the Poplar River)	Yes	Aquatic Life Warmwater Fishery	Riparian Alteration Flow Alteration Water Temperature	No	No	-----	Pallid sturgeon recovery priority area
Missouri River (Poplar River to MT/ND State line)	Yes	Aquatic Life Warmwater Fishery	Flow Alteration Water Temperature	No	No	-----	Pallid sturgeon recovery priority area
Garrison Reservoir	Yes	Fish and Other Aquatic Biota Fish Consumption	Low Dissolved Oxygen Water Temperature Methyl-Mercury	No	Yes	Mercury	Hypolimnetic dissolved oxygen
Missouri River (Garrison Dam tailwaters)	No	-----	-----	-----	Yes	Mercury	Low dissolved oxygen in Garrison Dam tailwaters (associated with late summer hypolimnetic reservoir withdrawals)
Oahe Reservoir (Cheyenne River Area)	No	----	-----	-----	Yes	Mercury	Issued by the Cheyenne River Sioux Tribe for Oahe Reservoir, Cheyenne River, and Moreau River within their tribal lands.
Lake Pocasse (Oahe Reservoir)	Yes	Warmwater Fishery	Trophic State Index (Eutrophication)	No	No	-----	-----
Big Bend Reservoir	No	-----	Sediment	Yes	No	-----	TMDL developed for sediment. A nonpoint source management project is being implemented in the Bad River watershed.
Missouri River (Fort Randall Dam to Gavins Point Reservoir)	No	-----	-----	-----	No	-----	National recreational river Pallid sturgeon recovery priority area
Gavins Point Reservoir	No	-----	-----	-----	No	-----	Sedimentation Emergent aquatic vegetation
Missouri River (Gavins Pt Dam to Rulo, NE)							Pallid sturgeon recovery priority area
• Gavins Pt Dam to Big Sioux River	No			-----	No		National recreational river
• Big Sioux River to Platte River	Yes	Aquatic Life	Dieldrin, PCBs	No	Yes	Dieldrin PCBs	Summer ambient water temperature (NPDES limitations regarding cooling water discharges)
• Council Bluffs, IA)	Yes	Drinking Water Supply	Arsenic	No	-----	-----	-----
• Platte River to Nebraska-Kansas Border	Yes	Recreation Aquatic Life	*E. coli* Bacteria Dieldrin, PCBs	Yes/No	Yes	Dieldrin PCBs	TMDL developed for *E. coli.* Summer ambient water temperature (NPDES limitations regarding cooling water discharges)

* Information taken from published State Total Maximum Daily Load (TMDL) 303(d) reports and listings as of March 1, 2009.

2 LIMNOLOGICAL PROCESSES IN RESERVOIRS

Many of the Corps civil works projects in the District involve the operation and maintenance of a reservoir or the regulation of flows discharged from reservoirs. Much of the water quality monitoring conducted by the District is done to determine existing water quality conditions and identify water quality management concerns at these reservoirs. A basic understanding of the limnological processes that occur in reservoirs is needed to interpret the water quality information provided in this report. The following discussion provides a basic overview of limnological processes that occur in reservoirs.

2.1 VERTICAL AND LONGITUDINAL WATER QUALITY GRADIENTS

The annual temperature distribution represents one of the most important limnological processes occurring within a reservoir. Thermal variation in a reservoir results in temperature-induced density stratification, and an understanding of the thermal regime is essential to water quality assessment. Deep, temperate-zone lakes typically completely mix from the surface to the bottom twice a year (i.e., dimictic). Temperate-zone dimictic lakes exhibit thermally-induced density stratification in the summer and winter months that is separated by periods of "turnover" in the spring and fall. This stratification typically occurs through the interaction of wind and solar insolation at the lake surface and creates density gradients that can influence lake water quality. During the summer, solar insolation has its highest intensity and the reservoir becomes stratified into three zones: 1) epilimnion, 2) metalimnion, and 3) hypolimnion.

<u>Epilimnion</u>: The epilimnion is the upper zone that consists of the less dense, warmer water in the reservoir. It is fairly turbulent since its thickness is determined by the turbulent kinetic energy inputs (e.g., wind, convection, etc.), and a relatively uniform temperature distribution throughout this zone is maintained.

<u>Metalimnion</u>: The metalimnion is the middle zone that represents the transition from warm surface water to colder bottom water. There is a distinct temperature gradient through the metalimnion. The metalimnion contains the thermocline that is the plane or surface of maximum temperature rate change.

<u>Hypolimnion</u>: The hypolimnion is the bottom zone of more dense, colder water that is relatively quiescent. Bottom withdrawal or fluctuating water levels in reservoirs, however, may significantly increase hypolimnetic mixing.

Long, dendritic reservoirs with tributary inflows located a considerable distance from the outflow and unidirectional flow from headwater to dam develop gradients in space and time (USACE, 1987). Although these gradients are continuous from headwater to dam, three characteristic zones result: a riverine zone, a zone of transition, and a lacustrine zone (USACE, 1987).

<u>Riverine Zone:</u> The riverine zone is relatively narrow and well mixed, and there is a significant decrease in water current velocities. Advective forces are still sufficient to transport significant quantities of suspended particles, such as silts, clays, and organic particulate. Light penetration in this zone is minimal and may be the limiting factor that controls primary productivity in the water column. The decomposition of tributary organic loadings often creates a significant oxygen demand, but an aerobic environment is maintained because the riverine zone is generally shallow and well mixed. Longitudinal dispersion may be an important process in this zone.

<u>Zone of Transition:</u> Significant sedimentation occurs through the transition zone, with a subsequent increase in light penetration. Light penetration may increase gradually or abruptly, depending on the flow regime. At some point within the mixed layer of the zone of transition, a

compensation point between the production and decomposition of organic matter should be reached. Beyond this point, production of organic matter within the reservoir mixed layer should begin to dominate.

Lacustrine Zone: The lacustrine zone is characteristic of a lake system. Sedimentation of inorganic particulate is low. Light penetration is sufficient to promote primary production, with nutrient levels the limiting factor and production of organic matter exceeds decomposition within the mixed layer. Entrainment of metalimnetic and hypolimnetic water, particulate, and nutrients may occur through internal waves or wind mixing during the passage of large weather fronts. Hypolimnetic mixing may be more extensive in reservoirs than "natural" lakes because of bottom withdrawal. In addition, an intake structure may simultaneously remove water from the hypolimnion and metalimnion.

When tributary inflow enters a reservoir, it displaces the reservoir water. If there is no density difference between the inflow and reservoir waters, the inflow will mix with the reservoir water as the inflow water moves toward the dam. However, if there are density differences between the inflow and reservoir waters, the inflow moves as a density current in the form of overflows, interflows, or underflows. Internal mixing is the term used to describe mixing within a reservoir from such factors as wind, Langmuir circulation, convection, Kelvin-Helmholtz instabilities, and outflow (USACE, 1987).

2.2 CHEMICAL CHARACTERISTICS OF RESERVOIR PROCESSES

2.2.1 CONSTITUENTS

Some of the most important chemical constituents in reservoir waters that affect water quality are needed by aquatic organisms for survival. These include oxygen, carbon, nitrogen, and phosphorus. Other important constituents are silica, manganese, iron, and sulfur.

Dissolved oxygen: Oxygen is a fundamental chemical constituent of waterbodies that is essential to the survival of aquatic organisms and is one of the most important indicators of reservoir water quality conditions. The distribution of dissolved oxygen (DO) in reservoirs is a result of dynamic transfer processes from the atmospheric and photosynthetic sources to consumptive uses by the aquatic biota. The resulting distribution of DO in the reservoir water strongly affects the solubility of many inorganic chemical constituents. Often, water quality control or management approaches are formulated to maintain an aerobic, or oxic (i.e., oxygen-containing), environment. Oxygen is produced by aquatic plants (phytoplankton and macrophytes) and is consumed by aquatic plants, other biological organisms, and chemical oxidations. In reservoirs, the DO demand may be divided into two separate but highly interactive fractions: sediment oxygen demand (SOD) and water column oxygen demand.

Sediment oxygen demand: The SOD is typically highest in the upstream area of the reservoir just below the headwaters. This is an area of transition from riverine to lake characteristics. It is relatively shallow but stratifies. The loading and sedimentation of organic matter is high in this transition area and, during stratification, the hypolimnetic DO to satisfy this demand can be depleted. If anoxic conditions develop, they generally do so in this area of the reservoir and progressively move toward the dam during the stratification period. The SOD is relatively independent of DO when DO concentrations in the water column are greater than 3 to 4 mg/l but becomes limited by the rate of oxygen supply to the sediments.

Water column oxygen demand: A characteristic of many reservoirs is a metalimnetic minimum in DO concentrations, or negative heterograde oxygen curve (Figure 2.1). Density interflows not only transport oxygen-demanding material into the metalimnion but can also entrain reduced chemicals from the upstream anoxic area and create additional oxygen demand. Organic matter and organisms from the mixed layer settle at slower rates in the metalimnion because of increased

viscosity due to lower temperatures. Since this labile organic matter remains in the metalimnion for a longer time period, decomposition occurs over a longer time, exerting a higher oxygen demand. Metalimnetic oxygen depletion is an important process in deep reservoirs. A hypolimnetic oxygen demand generally starts at the sediment/water interface unless underflows contribute organic matter that exerts a significant oxygen demand. In addition to metalimnetic DO depletion, hypolimnetic DO depletion also is important in shallow, stratified reservoirs since there is a smaller hypolimnetic volume of oxygen to satisfy oxygen demands than in deeper reservoirs.

Dissolved oxygen distribution: Two basic types of vertical DO distribution may occur in the water column: an orthograde and clinograde DO distribution (Figure 2.1). In the orthograde distribution, DO concentration is a function primarily of temperature since DO consumption is limited. The clinograde DO profile is representative of more productive, nutrient-rich reservoirs where the hypolimnetic DO concentration progressively decreases during stratification and can occur during both summer and winter stratification periods.

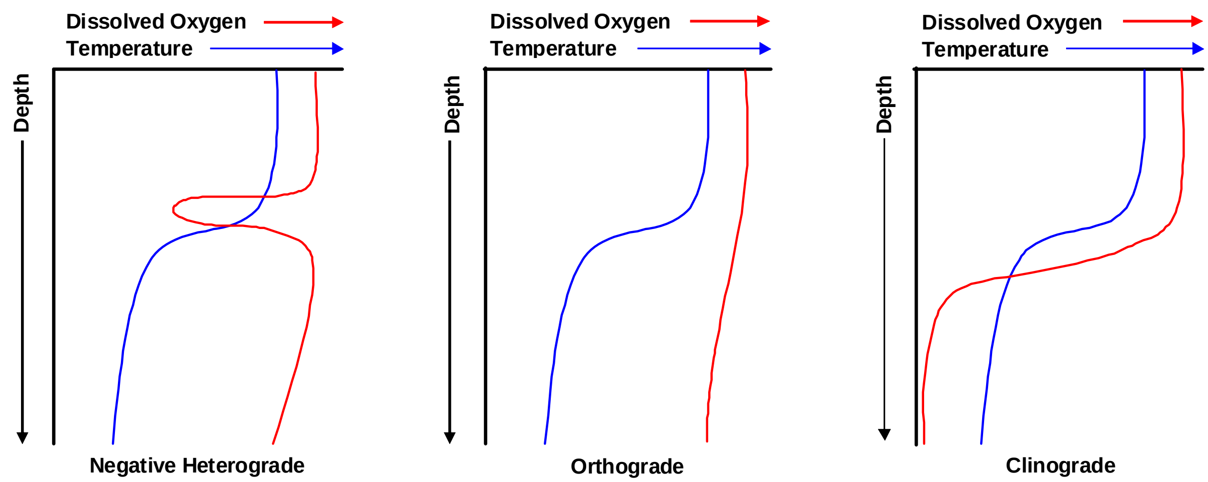

Figure 2.1. Vertical oxygen concentrations possible in thermally stratified lakes.

Inorganic carbon: Inorganic carbon represents the basic building block for the production of organic matter by plants. Inorganic carbon can also regulate the pH and buffering capacity or alkalinity of aquatic systems. Inorganic carbon exists in a dynamic equilibrium in three major forms: carbon dioxide (CO_2), bicarbonate ions (HCO_3), and carbonate ions (CO_3). Carbon dioxide is readily soluble in water and some CO_2 remains in a gaseous form, but the majority of the CO_2 forms carbonic acid that dissociates rapidly into HCO_3 and CO_3 ions. This dissociation results in a weakly alkaline system (i.e., pH ≈ 7.1 or 7.2). There is an inverse relationship between pH and CO_2. The pH increases when aquatic plants (phytoplankton or macrophytes) remove CO_2 from the water to form organic matter through photosynthesis during the day. During the night when aquatic plants respire and release CO_2, the pH decreases. The extent of this pH change provides an indication of the buffering capacity of the system. Weakly buffered systems with low alkalinities (i.e., <500 microequivalents per liter) experience larger shifts in pH than well-buffered systems (i.e., >1,000 microequivalents per liter).

Nitrogen: Nitrogen is important in the formulation of plant and animal protein. Nitrogen, similar to carbon, also has a gaseous form. Many species of cyanobacteria can use or fix elemental or gaseous N_2 as a nitrogen source. The most common forms of nitrogen in aquatic systems are ammonia (NH_3-N), nitrite (NO_2-N), and nitrate (NO_3-N). All three forms are transported in water in a dissolved phase. Ammonia results primarily from the decomposition of organic matter. Nitrite is primarily an intermediate compound in the oxidation or nitrification of ammonia to nitrate, while nitrate is the stable oxidation state of nitrogen and represents the other primary inorganic nitrogen form, besides NH_3, used by aquatic plants.

Phosphorus: Phosphorus is used by both plants and animals to form enzymes and vitamins and to store energy in organic matter. Phosphorus has received considerable attention as the nutrient controlling algal production and densities and associated water quality problems. The reasons for this emphasis are: phosphorus tends to limit plant growth more than the other major nutrients; phosphorus does not have a gaseous phase and ultimately originates from the weathering of rocks; removal of phosphorus from point sources can reduce the growth of aquatic plants; and the technology for removing phosphorus is more advanced and less expensive than nitrogen removal. Phosphorus is generally expressed in terms of the chemical procedures used for measurement: total phosphorus, particulate phosphorus, dissolved or filterable phosphorus, and soluble reactive phosphorus. Phosphorus is a very reactive element; it reacts with many cations such as iron and calcium and is readily sorbed on particulate matter such as clays, carbonates, and inorganic colloids. Since phosphorus exists in a particulate phase, sedimentation represents a continuous loss from the water column to the sediment. Sediment phosphorus, then, may exhibit longitudinal gradients in reservoirs similar to sediment silt/clay gradients. Phosphorus contributions from sediment under anoxic conditions and macrophyte decomposition are considered internal phosphorus sources or loads, and are in a chemical form readily available for plankton uptake and use. Internal phosphorus loading can represent a major portion of the total phosphorus budget.

Silica: Silica is an essential component of diatom algal frustules or cell walls. Silica uptake by diatoms can markedly reduce silica concentrations in the epilimnion and initiate a seasonal succession of diatom species. When silica concentrations decrease below 0.5 mg/l, diatoms generally are no longer competitive with other phytoplankton species.

Other nutrients: Iron, manganese, and sulfur concentrations generally are adequate to satisfy plant nutrient requirements. Oxidized iron (III) and manganese (IV) are quite insoluble in water and occur in low concentrations under aerobic conditions. Under aerobic conditions, sulfur usually is present as sulfate.

2.2.2 ANAEROBIC (HYPOXIC AND ANOXIC) CONDITIONS

When dissolved oxygen concentrations are reduced to approximately 2 to 3 mg/l, the oxygen regime is considered hypoxic. Anoxic conditions occur when there is a complete lack of oxygen. When hypoxic conditions occur in the hypolimnion, the oxygen regime at the sediment/water interface is generally considered anoxic, and anaerobic processes begin to occur in the sediment interstitial water. Nitrate reduction to ammonium and/or N_2O or N_2 (denitrification) is considered to be the first phase of the anaerobic process and places the system in a slightly reduced electrochemical state. Ammonium-nitrogen begins to accumulate in the hypolimnetic water. The presence of nitrate prevents the production of additional reduced forms such as manganese (II), iron (II), or sulfide species. Denitrification probably serves as the main mechanism for removing nitrate from the hypolimnion. Following the reduction or denitrification of nitrate, manganese species are reduced from insoluble forms (i.e., Mn (IV)) to soluble manganous forms (i.e., Mn (II)), which diffuse into the overlying water column. Nitrate reduction is an important step in anaerobic processes since the presence of nitrate in the water column will inhibit manganese reduction. As the electrochemical potential of the system becomes further reduced, iron is reduced from the insoluble ferric (III) form to the soluble ferrous (II) form and begins to diffuse into the overlying water column. Phosphorus, in many instances, is also transported in a complexed form with insoluble ferric (III) species; therefore, the reduction and solubilization of iron also result in the release and solubilization of phosphorus into the water column. The sediments may serve as a major phosphorus source during anoxic periods and a phosphorus sink during aerobic periods. During this period of anaerobiosis, microorganisms also are decomposing organic matter into lower molecular weight acids and alcohols such as acetic, fulvic, humic, and citric acids and methanol. These compounds may also serve as trihalomethane precursors (low-molecular weight organic compounds in water; i.e., methane, formate acetate), which, when subject to chlorination during water treatment, form trihalomethanes, or THMs

(carcinogens). As the system becomes further reduced, sulfate is reduced to sulfide, which begins to appear in the water column. Sulfide will readily combine with soluble reduced iron (II), however, to form insoluble ferrous sulfide, which precipitates out of solution. If the sulfate is reduced to sulfide and the electrochemical potential is strongly reducing, methane formation from the reduced organic acids and alcohols may occur. Consequently, water samples from anoxic depths will exhibit these chemical characteristics.

Anaerobic processes are generally initiated in the upstream portion of the hypolimnion where organic loading from the inflow is relatively high and the volume of the hypolimnion is minimal, so oxygen depletion occurs rapidly. Anaerobic conditions are generally initiated at the sediment/water interface and gradually diffuse into the overlying water column and downstream toward the dam. Anoxic conditions may also develop in a deep pocket near the dam due to decomposition of autochthonous organic matter settling to the bottom. This anoxic pocket, in addition to expanding vertically into the water column, may also move upstream and eventually meet the anoxic zone moving downstream.

Anoxic conditions are generally associated with the hypolimnion, but anoxic conditions may occur in the metalimnion. The metalimnion may become anoxic due to microbial respiration and decomposition of plankton settling into the metalimnion, microbial metabolism of organic matter entering as an interflow, or entrainment of anoxic hypolimnetic water from the upper portion of the reservoir.

2.3 BIOLOGICAL CHARACTERISTICS AND PROCESSES

2.3.1 MICROBIOLOGICAL

The microorganisms associated with reservoirs may be categorized as pathogenic or nonpathogenic. Pathogenic microorganisms are of a concern from a human health standpoint and may limit recreational and other uses of reservoirs. Nonpathogenic microorganisms are important in that they often serve as decomposers of organic matter and are a major source of carbon and energy for a reservoir. Microorganisms generally inhabit all zones of the reservoir as well as all layers. Seasonally high concentrations of bacteria will occur during the warmer months, but they can be diluted by high discharges. Anaerobic conditions enhance growth of certain bacteria while aeration facilitates the use of bacterial food sources. Microorganisms, bacteria in particular, are responsible for mobilization of contaminants from sediments.

2.3.2 PHOTOSYNTHESIS

Oxygen is a by-product of aquatic plant photosynthesis, which represents a major source of oxygen for reservoirs during the growing season. Oxygen solubility is less during the period of higher water temperatures, and diffusion may also be less if wind speeds are lower during the summer than the spring or fall. Biological activity and oxygen demand typically are high during thermal stratification, so photosynthesis may represent a major source of oxygen during this period. Oxygen supersaturation in the euphotic zone can occur during periods of high photosynthesis.

2.3.3 PLANKTON

Phytoplankton influence dissolved oxygen and suspended solids concentrations, transparency, taste and odor, aesthetics, and other factors that affect reservoir uses and water quality objectives. Phytoplankton are a primary source of organic matter production and form the base of the autochthonous food web in many reservoirs since fluctuating water levels may limit macrophyte and periphyton production. Phytoplankton can be generally grouped as diatoms, green algae, cyanobacteria, or cryptomonad algae. Chlorophyll *a* represents a common variable used to estimate phytoplankton biomass.

Seasonal succession of phytoplankton species is a natural occurrence in reservoirs. The spring assemblage is usually dominated by diatoms and cryptomonads. Silica depletion in the photic zone and increased settling as viscosity decreases because of increased temperatures usually result in green algae succeeding the diatoms. Decreases in nitrogen or a decreased competitive advantage for carbon at higher pH may result in cyanobacteria succeeding the green algae during summer and fall. Diatoms generally return in the fall, but cyanobacteria, greens, or diatoms may cause algae blooms following fall turnover when hypolimnetic nutrients are mixed throughout the water column. The general pattern of seasonal succession of phytoplankton is fairly constant from year to year. However, hydrologic variability, such as increased mixing and delay in the onset of stratification during cool, wet spring periods, can maintain diatoms longer in the spring and shift or modify the successional pattern of algae in reservoirs.

Phytoplankton grazers can reduce the abundance of algae and alter their successional patterns. Some phytoplankton species are consumed and assimilated more readily and are preferentially selected by consumers. Single-celled diatom and green algae species are readily consumed by zooplankton, while filamentous cyanobacteria are avoided by zooplankters. Altering the fish population can result in a change in the zooplankton population that can affect the phytoplankton population.

2.3.4 ORGANIC CARBON AND DETRITUS

Total organic carbon (TOC) is composed of dissolved organic carbon (DOC) and particulate organic carbon (POC). Detritus represents that portion of the POC that is nonliving. Nearly all the TOC of natural waters consists of DOC and detritus, or dead POC. The processes of decomposition and consumption of TOC are important in reservoirs and can have a significant affect on water quality.

DOC and POC are decomposed by microbial organisms. This decomposition exerts an oxygen demand that can remove dissolved oxygen from the water column. During stratification, the metalimnion and hypolimnion become relatively isolated from sources of dissolved oxygen, and depletion can occur through organic decomposition. There are two major sources of this organic matter: allochthonous (i.e., produced outside the reservoir and transported in) and autochthonous (i.e., produced within the reservoir). Allochthonous organic carbon in small streams may be relatively refractory since it consists of decaying terrestrial vegetation that has washed or fallen into the stream. Larger rivers, however, may contribute substantial quantities of riverine algae or periphyton that decompose rapidly and can exert a significant oxygen demand. Autochthonous sources include dead plankton settling from the mixed layers and macrophyte fragments and periphyton transported from the littoral zone. These sources are also rapidly decomposed.

POC and DOC absorbed onto sediment particles may serve as a major food source for aquatic organisms. The majority of the phytoplankton production enters the detritus food web with a minority being grazed by primary consumers (USACE, 1987). While autochthonous production is important in reservoirs, typically as much as three times the autochthonous production may be contributed by allochthonous material (USACE, 1987).

2.4 BOTTOM WITHDRAWAL RESERVOIRS

Bottom withdrawal structures are located near the deepest part of a reservoir. Bottom withdrawal removes hypolimnetic water and nutrients and may promote movement of interflows or underflow into the hypolimnion. They release cold water from the deep portion of the reservoir; however, this water may be hypoxic or anoxic during periods of stratification. Bottom outlets can cause density interflows or underflows (e.g., flow laden with sediment or dissolved solids) through the reservoir and generally provide little or no direct control over release water quality.

3 MAINSTEM SYSTEM WATER QUALITY MONITORING

3.1 MAINSTEM SYSTEM RESERVOIRS

3.1.1 LONG-TERM, FIXED-STATION AMBIENT MONITORING

Long-term, fixed-station ambient water quality monitoring has occurred at the six Mainstem System reservoirs (i.e., Fort Peck, Garrison, Oahe, Big Bend, Fort Randall, and Gavins Point) for the past 30 years. Recent ambient monitoring conducted by the District at the Mainstem System reservoirs included monthly (i.e., May through September) water quality monitoring at a near-dam, deepwater site. At Garrison, Fort Peck, and Oahe Reservoirs, additional long-term ambient sites were added, respectively, in 2006, 2007, and 2008. At Garrison Reservoir, the added sites included three reservoir deepwater locations (Beulah Bay, RM1412; Deepwater Bay, RM1445; and New Town, RM1481) and one inflow location (Missouri River near Williston, ND, RM1553). At Fort Peck Reservoir, the added sites included two reservoir deepwater locations (Hell Creek Bay, RM1805 and Rock Creek Bay, upper reaches of Dry Creek Arm) and one inflow location (Missouri River near Landusky, MT, RM1921). At Oahe Reservoir, the added sites included three reservoir deepwater locations (Cheyenne River, RM1110; Whitlocks Bay, RM11153; and Mobridge, RM1196) and one inflow location (Missouri River at Bismarck, ND, RM1315). Water quality monitoring included field measurements and collection of water samples for analytical analysis. Field measurements included surface water transparency (i.e., Secchi depth) and measuring temperature, dissolved oxygen, pH, conductivity, oxidation-reduction potential (ORP), turbidity, and chlorophyll *a* at 1-meter increments from the reservoir surface to the bottom. Near-surface and near-bottom grab samples were collected and delivered to the laboratory where they were analyzed for alkalinity, nitrate/nitrite, total ammonia, total Kjeldahl nitrogen, total and dissolved phosphorus, ortho-phosphorus, suspended solids, total organic carbon, pesticides, and various metals. A near-surface grab sample was also collected in the epilimnion for analysis of chlorophyll *a*, the cyanobacteria toxin microcystin, and phytoplankton taxa occurrence and relative abundance.

3.1.2 BACTERIA MONITORING AT SWIMMING BEACHES

The District has cooperated with the Nebraska Department of Environmental Quality (NDEQ) to monitor bacteria levels present at swimming beaches at the Gavins Point project over the past 5 years. Five swimming beaches on Gavins Point Reservoir and one on Lake Yankton were monitored. Weekly grab samples were collected from May through September and analyzed for fecal coliform and *E. coli* bacteria and the cyanobacteria toxin microcystin. The bacteria monitoring was conducted to meet a 6-hour holding time for collected samples.

3.1.3 INTENSIVE WATER QUALITY SURVEYS

3.1.3.1 Fort Randall Reservoir

The District completed a 3-year intensive water quality survey at Fort Randall Reservoir in 2008. The monitoring objectives of the intensive survey were to collect water quality data to spatially describe water quality conditions present in Fort Randall Reservoir during the late spring and summer and to collect information to facilitate the application of the CE-QUAL-W2 hydrodynamic and water quality model. As part of the intensive survey, seven reservoir sites and two inflow sites were monitored. The seven reservoir sites were relatively equally spaced in deepwater areas from Fort Randall Dam to near Chamberlain, SD. The inflow sites were located on the Missouri and White Rivers and were meant to represent water quality conditions of water flowing into Fort Randall Reservoir. Monthly samples at the reservoir and inflow sites were collected during June through September.

Water quality monitoring at the reservoir sites included field measurements for depth profiling and water transparency and collection of near-surface and near-bottom water samples for laboratory analysis. Monitoring at the inflow sites included field measurements and collection of a near-surface water sample for laboratory analysis. Reservoir depth profiles in 1-meter increments were recorded for temperature, dissolved oxygen, pH, conductivity, ORP, chlorophyll *a*, and turbidity. Field measurements taken at the inflow sites included temperature, dissolved oxygen, pH, conductivity, ORP, and turbidity. Near-surface and near-bottom grab samples were analyzed for alkalinity, nitrate/nitrite, total ammonia, total Kjeldahl nitrogen, total phosphorus, ortho-phosphorus, dissolved total phosphorus, total suspended solids, total dissolved solids, total organic carbon, sulfate, iron (total and dissolved), and manganese (total and dissolved). The near-surface samples were also analyzed for chlorophyll *a*, the cyanobacteria toxin microcystin, and phytoplankton taxa occurrence and relative abundance.

3.1.3.2 <u>Big Bend and Gavins Point Reservoir</u>

The District completed the first year of planned 3-year intensive water quality surveys at Big Bend and Gavins Point Reservoirs in 2008. The monitoring objectives of the intensive surveys were to collect water quality data to spatially describe water quality conditions present in the reservoirs during the summer and to collect information to facilitate the application of the CE-QUAL-W2 hydrodynamic and water quality model. As part of the intensive surveys, five reservoir sites and one inflow site were monitored. The five reservoir sites at Big Bend Reservoir were relatively equally spaced in deepwater areas from Big Bend Dam to near Pierre, SD. The inflow site was located on the Bad River and was meant to represent water quality conditions of water flowing into Big Bend Reservoir. The five reservoir sites at Gavins Point Reservoir were relatively equally spaced in deepwater areas from Gavins Point Dam to near Springfield, SD. The inflow site was located on the Niobrara River and was meant to represent water quality conditions of water flowing into the Missouri River just upstream from Gavins Point Reservoir. At both Big Bend and Gavins Point Reservoirs, the monitored discharge of the upstream dams (i.e., Oahe and Fort Randall Dams) was taken to represent the water quality conditions of the inflowing Missouri River. Monthly samples at the reservoir and inflow sites were collected during June through September.

Water quality monitoring at the reservoir sites included field measurements for depth profiling and water transparency and collection of near-surface and near-bottom water samples for laboratory analysis. Monitoring at the inflow site included field measurements and collection of a near-surface water sample for laboratory analysis. Reservoir depth profiles in 1-meter increments were recorded for temperature, dissolved oxygen, pH, conductivity, ORP, chlorophyll *a*, and turbidity. Field measurements taken at the inflow sites included temperature, dissolved oxygen, pH, conductivity, ORP, and turbidity. Near-surface and near-bottom grab samples were analyzed for alkalinity, nitrate/nitrite, total ammonia, total Kjeldahl nitrogen, total phosphorus, ortho-phosphorus, dissolved total phosphorus, total suspended solids, total dissolved solids, total organic carbon, sulfate, iron (total and dissolved), and manganese (total and dissolved). The near-surface samples were also analyzed for chlorophyll *a*, the cyanobacteria toxin microcystin, and phytoplankton taxa occurrence and relative abundance.

3.2 MAINSTEM SYSTEM POWERPLANTS

As part of the operation of the Mainstem System powerplants, water is drawn from the intake structure of each dam and piped through the powerplant in a "raw water" supply line that is tapped for various uses. The "raw water" supply line is an open-ended, flow-through system (i.e., water is continually discharged). A monitoring station, that measures water quality conditions of water drawn from near the start of the "raw water" supply line, has been irregularly maintained at each of the powerplants over the past several years. Recent water quality monitoring has consisted of year-round,

hourly measurements of temperature and dissolved oxygen through the use of a data-logger. Monthly grab samples (year-round) have also been collected and analyzed for alkalinity, nitrate/nitrite, total ammonia, total Kjeldahl nitrogen, total and dissolved phosphorus, ortho-phosphorus, total suspended solids, total dissolved solids, total organic carbon, sulfate, pesticides, and various metals. The rate of dam discharge when measurements and samples were taken was determined from powerplant records. The water quality conditions measured in the "raw water" supply lines of the Mainstem System powerplants are believed to represent the water quality conditions present in the reservoirs near the dam intakes and in the tailwaters (i.e., Missouri River) immediately downstream of the dam.

3.3 MISSOURI RIVER FROM FORT RANDALL DAM TO RULO, NE

Since 2003, the District has cooperated with the State of Nebraska (NDEQ) to monitor ambient water quality conditions along the Missouri River from Fort Randall Dam to Rulo, Nebraska. Fixed-station monitoring has occurred at the following nine sites: Fort Randall Dam tailwaters; near Verdel, NE; Gavins Point Dam tailwaters; near Maskell, NE; near Ponca, NE; at Decatur, NE; at Omaha, NE; at Nebraska City, NE; and at Rulo, NE. Water quality monitoring consisted of collecting monthly near-surface grab samples year-round. The grab samples were collected from the bank in an area of fast current. The collected grab samples were analyzed for alkalinity, nitrate/nitrite, total ammonia, total Kjeldahl nitrogen, total phosphorus, total suspended solids, total organic carbon, chemical oxygen demand, chloride, pesticides, and various metals. Field measurements taken at the time of sample collection included temperature, pH, dissolved oxygen, conductivity, ORP, and turbidity.

3.4 MAINSTEM SYSTEM ANCILLARY LAKES – LAKE YANKTON, LAKE POCASSE, AND LAKE AUDUBON

Lake Yankton, Lake Pocasse, and Lake Audubon are ancillary lakes to the Mainstem System reservoirs located respectively at the Gavins Point, Oahe, and Garrison projects. Water quality monitoring at these three lakes has been sporadic in the past. The Omaha District initiated ambient water quality monitoring at the lakes in 2006 as part of a 3-year rotational monitoring cycle. However, low-water conditions prevented boat access and, therefore, prevented water quality monitoring at Lake Pocasse in 2006. The three ancillary lakes are scheduled to be monitored again in 2009. Targeted monitoring at the three lakes includes monthly monitoring (May through September) at a near-dam deepwater location. The monitoring includes field measurements for depth profiling and water transparency and collection of near-surface and near-bottom water samples for laboratory analysis. Depth profiles include measuring temperature, dissolved oxygen, pH, conductivity, ORP, turbidity, and chlorophyll *a* in 1-meter increments. Near-surface and near-bottom grab samples are analyzed for alkalinity, nitrate/nitrite, total ammonia, Kjeldahl nitrogen, total phosphorus, orthophosphorus, total suspended solids, total organic carbon, chlorophyll *a*, microcystin, pesticides, and various metals.

4 WATER QUALITY ASSESSMENT METHODS

4.1 EXISTING WATER QUALITY (2004 THROUGH 2008)

For the purposes of this report, existing water quality is defined as water quality conditions that occurred during the past 5 years (i.e., 2004 through 2008). Water quality monitoring conducted during that period was used to describe existing water quality conditions.

4.1.1 STATISTICAL SUMMARY AND COMPARISON TO APPLICABLE WATER QUALITY STANDARDS CRITERIA

Statistical analyses were performed on the water quality monitoring data collected at the Mainstem System reservoirs (including inflow and outflow sites), powerplants, on the Missouri River, and at the Mainstem System ancillary lakes. Descriptive statistics were calculated to describe central tendencies and the range of observations in existing water quality. Monitoring results were compared to applicable water quality standards criteria established by the appropriate States pursuant to the Federal CWA. Tables were constructed that list the parameters measured; number of observations; and the mean, median, minimum, and maximum of the data collected. The constructed tables also list the water quality standards criteria applicable to the individual parameters and the frequency that these criteria were not met.

4.1.2 SPATIAL VARIATION IN WATER QUALITY CONDITIONS

4.1.2.1 Longitudinal Variation

4.1.2.1.1 Reservoir Contour Plots

Longitudinal contour plots were constructed when adequate depth-profile measurements were collected along the length of a reservoir. Adequate information was collected in 2008 to construct longitudinal contour plots at all six Mainstem System reservoirs. Longitudinal contour plots were constructed for water temperature, dissolved oxygen, and turbidity. The longitudinal contour plots were constructed using the "Hydrologic Information Plotting Program" included in the "Data Management and Analysis System for Lakes, Estuaries, and Rivers" (DASLER-X) software developed by HydroGeoLogic Inc. (HydroGeoLogic Inc., 2005).

4.1.2.1.2 Reservoir Box Plots

Longitudinal box plots were constructed when adequate measurements were collected along the length of a reservoir and significant variation was observed in the measurements. Adequate information was collected to construct longitudinal box plots of existing water quality conditions at all six Mainstem System reservoirs.

4.1.2.1.3 Lower Missouri River Box Plots

Longitudinal box plots were constructed for the lower Missouri River. The box plots were constructed from the water quality monitoring conducted in cooperation with the NDEQ during the period 2004 through 2008. The box plots orient and display the distribution of selected water quality parameters measured at the seven monitored sites from Gavins Point Dam to Rulo, NE.

4.1.2.2 Vertical Variation in Lake Water Quality

Depending on their depth and bathymetry, lakes can experience thermally-induced density stratification in the summer. This can lead to significant vertical water quality variation if anoxic or near-anoxic conditions develop in the hypolimnion.

4.1.2.2.1 Summer Depth-Profile Plots

Measured water temperature and dissolved oxygen depth profiles were plotted at the Mainstem System reservoirs and Mainstem System ancillary lakes. The plotted depth profiles were measured at the near-dam, deepwater ambient monitoring location. Depth profiles measured in the months of July, August, and September over the past 5 years were plotted. The plots were reviewed to assess the occurrence of thermal stratification and hypolimnetic dissolved oxygen degradation.

4.1.2.2.2 Comparison of Near-Surface and Near-Bottom Water Quality Conditions

The variation of selected parameters with depth was evaluated by comparing paired near-surface and near-bottom collected samples. The compared paired samples were collected at the near-dam, deepwater monitoring location over the past 5 years. The parameters compared included water temperature, dissolved oxygen, ORP, pH, alkalinity, total organic carbon (TOC), total Kjeldahl nitrogen, total ammonia, and total phosphorus.

4.1.3 TEMPORAL VARIATION IN WATER QUALITY CONDITIONS

4.1.3.1 Time Series Plots of Mean Daily Water Temperatures Measured in the Missouri River Upstream and Downstream of the Mainstem System Reservoirs

Annual seasonal time series plots of mean daily water temperatures measured in the Missouri River immediately upstream and downstream of the Mainstem System reservoirs were constructed to display temporal and spatial variation.

4.1.3.2 Time-Series Plots of Flow, Water Temperature, and Dissolved Oxygen of Water Discharged through the Mainstem System Dams

Time series plots were prepared for water quality conditions monitored at the Missouri River Mainstem System powerplants during 2005 through 2008. Hourly water temperature, dissolved oxygen, and dam discharge were plotted semi-annually for the 4 years. Water temperature and dissolved oxygen plots represent monitoring of water drawn from the "raw water" supply line in each powerplant.

4.1.4 TROPHIC STATUS

A Trophic State Index (TSI) was calculated, as described by Carlson (1977). TSI values were determined from Secchi depth transparency, total phosphorus, and chlorophyll *a* measurements. Values for these three parameters were converted to an index number ranging from 0 to 100 according to the following equations:

$$\text{TSI(Secchi Depth)} = \text{TSI(SD)} = 10[6 - (\ln SD/\ln 2)]$$
$$\text{TSI(Chlorophyll } a) = \text{TSI(Chl)} = 10[6 - ((2.04\text{-}0.68 \ln Chl)/\ln 2)]$$
$$\text{TSI(Total Phosphorus)} = \text{TSI(TP)} = 10[6 - (\ln (48/TP)/\ln 2)]$$

Accurate TSI values from total phosphorus depend on the assumptions that phosphorus is the major limiting factor for algal growth and that the concentrations of all forms of phosphorus present are a

function of algal biomass. Accurate TSI values from Secchi depth transparency depend on the assumption that water clarity is primarily limited by phytoplankton biomass. Carlson indicates that the chlorophyll TSI value may be a better indicator of a lake's trophic conditions during mid-summer when algal productivity is at its maximum, while the total phosphorus TSI value may be a better indicator in the spring and fall when algal biomass is below its potential maximum. Calculation of TSI values from data collected from a lake's epilimnion during summer stratification provide the best agreement between all of the index parameters and facilitate comparisons between lakes. A TSI average value, calculated as the average of the three individually determined TSI values, is used by the District as an overall indicator of a reservoir's trophic state. The District uses the criteria defined in Table 4.1 for determining lake trophic status from TSI values.

Table 4.1. Lake trophic status based on calculated TSI values.

TSI	Trophic Condition
0-35	Oligotrophic
36-50	Mesotrophic
51-55	Moderately Eutrophic
56-65	Eutrophic
66-100	Hypereutrophic

4.1.5 MAINSTEM SYSTEM RESERVOIR PHYTOPLANKTON COMMUNITY

Assessment of the phytoplankton community was based on grab samples that were analyzed by a contract laboratory. Laboratory analyses consisted of identification of phytoplankton taxa to the lowest practical level and quantification of taxa biovolume. These results were used to determine the relative abundance of phytoplankton taxa at the division level based on the measured biovolumes.

4.1.6 IMPAIRMENT OF DESIGNATED WATER QUALITY-DEPENDENT BENEFICIAL USES

Water quality-dependent beneficial uses are designated to waterbodies in State water quality standards and criteria are defined to protect these uses. Water quality data collected by the District during the 5-year period 2004 through 2008 were assessed to determine if water quality conditions were impairing the designated beneficial uses. These data were assessed using the methodologies defined by the appropriate States in developing their 2008 (or latest) Integrated Reports pursuant to the Federal CWA. It is noted that the "official" determination of whether water quality-dependent beneficial uses are impaired, pursuant to the Federal CWA, is by the States pursuant to their Section 305(b) and Section 303(d) assessments compiled in their biennial Integrated Water Quality Reports (See Table 1.3).

4.1.6.1 Montana Assessment Methodologies

The State of Montana requires that beneficial use support determinations be based on sufficient and credible data. Once sufficient and credible data are established, use support determinations are made based on defined assessment criteria (MDEQ, 2006). Assessment criteria for aquatic life, drinking water, and recreation use support applicable to water quality monitoring data collected by the District are given in Tables 4.2 through 4.4.

Table 4.2. Aquatic life use support assessment criteria defined by Montana and applicable to data collected by the District.

Data Type	Beneficial Use Impairment: Unimpaired or Least Impaired	Moderately Impaired	Severely Impaired
Chemical Toxicants (i.e., Trace Metals and Ammonia)	• No exceedence of acute water quality standard. • Exceedences of chronic water quality standard ≤10% (no more than once for one parameter in a 3-year period when measurements were taken at least 4 times/year).	• Exceedences of acute water quality standard 1 to 25%. • Exceedences of chronic water quality standard 11 to 50%. • Exceedences of chronic water quality standard 1 to 10% of a "large" data set.	• Exceedences of acute water quality standard >25%. • Exceedences of chronic water quality standard >50%. • Exceedences of chronic water quality standard >10% of a "large" data set.
Trophic Status	Trophic status is similar to reference conditions.	Trophic status exceeds reference conditions.	Trophic status is hypereutrophic.
Chemistry (i.e., Nutrients, D.O., pH, TSS, Turbidity, Temp.)	Exceedences of water quality standard ≤10% of a "large" data set.	Exceedences of water quality standard 11 to 25% of a "large" data set.	Exceedences of water quality standard >25% of a "large" data set.
Nutrients	Nutrient concentrations are similar to reference conditions.	Nutrient concentrations are moderately higher than reference conditions.	Nutrient concentrations are substantially higher then reference conditions.
Biological Assemblage (i.e., Phytoplankton)	Data indicate functioning sustainable biological assemblage (>75% of reference condition).	Data indicate moderate impairment (25 to 75% of reference condition).	Data indicate severe impairment (<25% of reference condition).
Chlorophyll a	The chlorophyll levels are similar to reference conditions.	The chlorophyll level is moderately higher than reference condition.	The chlorophyll level is substantially greater than reference condition

Table 4.3. Drinking water use support assessment criteria defined by Montana and applicable to data collected by the District.

Data Type	Beneficial Use Impairment: Unimpaired or Least Impaired	Moderately Impaired	Severely Impaired
Chemistry (i.e., Inorganics, Organics)	No human health standard exceedences.	Not applicable.	Exceedence of human health standards.

Table 4.4. Recreation use support assessment criteria defined by Montana and applicable to data collected by the District.

Data Type	Beneficial Use Impairment: Unimpaired or Least Impaired	Moderately Impaired	Severely Impaired
Algae, Toxins, etc.	There are no excessive algae blooms, turbidity, odor, toxins, etc.; similar to reference conditions.	Excessive algae blooms, turbidity, odor, toxins, etc. moderately restrict swimming or boating.	Swimming or boating severely inhibited by excessive algae blooms, pathogens, turbidity, odor, toxins, etc.
Chlorophyll a	The benthic chlorophyll level is similar to reference condition; or the chlorophyll is <50 mg/m^2.	The benthic chlorophyll level moderately exceeds reference condition; or the chlorophyll is 50 to 100 mg/m^2.	The benthic chlorophyll level greatly exceeds reference condition; or the chlorophyll is >100 mg/m^2.

4.1.6.2 <u>Nebraska Assessment Methodologies</u>

4.1.6.2.1 Assessment of Physicochemical Data

Nebraska water quality standards define acute and chronic numeric criteria for the protection of aquatic life and maximum criteria for the protection of public drinking and agricultural water supplies. Nebraska deems a designated use to be impaired if measured water quality conditions indicate that numeric criteria are exceeded more than 10 percent of the time over an assessed 5-year period (NDEQ, 2007). To address the uncertainty associated with water quality data, the application of the 10 percent exceedence criterion is based on the number of measurements for the appropriate water quality criteria. Table 4.5 gives the Nebraska assessment measures regarding sample size and the number of exceedences that indicate an impaired use (i.e., 10% exceedence) at a 90% confidence level (i.e., $\alpha = 0.10$).

Table 4.5. State of Nebraska Assessment Measures for Sample Size and Number of Exceedences Required to Determine an Impaired Use (i.e., 10% Exceedence).

Sample Size (n)	Number of Observations Exceeding a Criterion Required to Define an Impaired Use	Sample Size (n)	Number of Observations Exceeding a Criterion Required to Define an Impaired Use
<12	3	56 - 63	10
12 – 18	4	64 - 71	11
19 - 25	5	72 - 79	12
26 - 32	6	80 - 88	13
33 - 40	7	89 - 96	14
41 - 47	8	97 - 100	15
48 - 55	9	>100	Not Defined

4.1.6.2.2 Assessment of Fecal Coliform and *E. coli* Bacteria Data

Table 4.6 summarizes the Nebraska measures for the assessment of the Primary Contact Recreation Beneficial Use using fecal coliform and *E. coli* bacteria data.

Table 4.6. State of Nebraska measures for the assessment of the Primary Contact Recreation Beneficial Use using fecal coliform and *E. coli* bacteria data.

Parameter	Water Quality Criteria (Geometric Mean)	Supported	Impaired
Fecal Coliform	≤ 200cfu/100ml	Season geometric mean ≤ 200cfu/100ml	Season geometric mean > 200cfu/100ml
E. coli	≤ 126cfu/100ml	Season geometric mean ≤ 126cfu/100ml	Season geometric mean > 126cfu/100ml

4.1.6.2.3 Assessment of Reservoir Sedimentation

It is the State of Nebraska's position that excess sediment delivered to a lake can cause several problems including "objectionable colors, turbidity, and deposits." Deposition of sediment can displace or eliminate fish spawning and rearing and other aquatic habitats. Also, the recreation area of a lake can be reduced or rendered undesirable. Nebraska uses two measurements to assess lake sedimentation regarding the use of aesthetics: impoundment volume loss and sedimentation rate. Both the lake volume loss and sedimentation rate are based on the "as-built" conditions of the lake. Table 4.7 summarizes the Nebraska criteria for the assessment of lakes regarding sedimentation.

Table 4.7. State of Nebraska measures for the assessment of lake sedimentation data.

Minimum Assessment Period	Supported	Impaired
≥5 Years	Volume loss < 25%, and Annual sedimentation rate ≤0.75%	Volume loss ≥ 25%, and Annual sedimentation rate >0.75%

4.1.6.2.4 Assessment of Reservoir Nutrient Data

Nebraska contends that excessive nutrient concentrations can promote adverse effects to water quality and biological populations within lakes. Some of these effects include reductions in dissolved oxygen, water clarity, biodiversity, and fish and wildlife habitat; and increases in bacteria concentrations, toxin mobility, ammonia toxicity, and in-lake filling. Nebraska uses the term "nutrients" to refer specifically to total nitrogen and total phosphorus. The presence of nitrogen and phosphorus do not directly impair uses; rather, the nutrients spur algal and other vegetative growth that causes use impairment from algal toxins, extreme diurnal pH fluctuations, and dissolved oxygen depletion. Table 4.8 summarizes the Nebraska measures for the assessment of lakes regarding nutrients.

Table 4.8. State of Nebraska measures for the assessment of lakes regarding nutrients.

Beneficial Use	Parameter 1	Assessment 1	Parameter 2	Assessment Value
Aesthetics	Chlorophyll *a*	Growing Season Avg. > Site-Specific Criterion	Total Nitrogen or Total Phosphorus	Growing Season Avg. > Site-Specific Criteria
Aesthetics	Microcystin	> 20 ug/l	-----	-----
Aquatic Life	pH	<6.5 or > 9.0	Chlorophyll *a*	Growing Season Avg. > Site-Specific Criterion
Aquatic Life	Dissolved Oxygen	> Aquatic Life Criteria	Chlorophyll *a*	Growing Season Avg. > Site-Specific Criterion

4.1.6.3 North Dakota Assessment Methodologies

Water quality standards are the fundamental benchmarks North Dakota uses to assess surface water quality and determine beneficial use impairment status. North Dakota requires that beneficial use assessments be based on sufficient and credible data. The State criteria for sufficient and credible chemical, physical, and biological data are given in Table 4.9.

4.1.6.3.1 Assessment of Beneficial Use Support for Aquatic Life Based on Physicochemical Data

In general, aquatic life use determinations utilizing chemical data are based on the number of exceedences of the current State water quality standards criteria for dissolved oxygen, pH, and temperature; and on the number of exceedences of the acute or chronic standards for ammonia, aluminum, arsenic, cadmium, chromium, copper, cyanide, lead, nickel, selenium, silver, and zinc. The acute and chronic water quality standards criteria for trace metals are expressed as total recoverable metals and not as dissolved metals. However, where dissolved metals data are available, use support assessments are made by applying the dissolved metals data to the water quality standards criteria expressed as the total recoverable fraction. Table 4.10 gives the use support decision criteria that North Dakota uses to assess aquatic life use based on physicochemical data.

Table 4.9. State of North Dakota criteria for determining if data are sufficient and credible data for beneficial use impairment assessments.

• Data collection and analysis followed known and documented quality assurance/quality control procedures.
• Water column chemical or biological data are 10 years old or les for rivers, streams, lakes, and reservoirs; unless there is adequate justification to use older data (e.g., land use, watershed, or climatic conditions have not changed. Data for all 10 years of the period are not required to make an assessment.
• There are a minimum of 10 chemical samples collected in the 10-year period for rivers and streams. The 10 samples may range from one sample collected in each of 10 years or 10 samples collected all in 1 year.
• There should be a minimum of two samples collected from lakes or reservoirs collected during the growing season, May through September. The samples may consist of two samples collected the same year or samples collected in separate years.
• For all criteria that are expressed as a 30-day arithmetic average (e.g., chloride, sulfate, etc.) a minimum of four daily samples must be collected during any consecutive 30-day period. Samples collected during the same day shall be averaged and treated as one daily sample.
• Data collection and analysis followed known and documented quality assurance/quality control procedures.
• There are situations where a single set of data is all that is needed to make a use support determination. For example, a single set of water chemistry data may be sufficient to establish that a waterbody is not supporting aquatic life use. In such situations where a single data set irrefutably proves that impairment exists, an impairment determination may be based on this "overwhelming evidence." Data cannot be overwhelming evidence unless the methods used for collection and analysis meets the most stringent standards for reliability and validity. It must be certain that the data are representative of actual current waterbody conditions. The data must be representative of the spatial extent of the waterbody and of relevant temporal patterns. Data more than 3 or 4 years old should not be used as overwhelming evidence unless there is a strong basis for concluding that conditions have not changed since the data were collected.

Table 4.10. Aquatic life use support decision criteria defined by North Dakota for physicochemical data.

Aquatic Life Use Support	Criteria for Determining Use Support
Full Support	• Dissolved oxygen (DO) and pH: DO criterion of 5 mg/l (daily minimum) and pH criteria of 7 and 9 S.U. (daily minimum and maximum) not exceeded or exceeded in <10% of the samples and there is no record of lethality to aquatic biota. • Temperature: Daily maximum criterion of 29.4°C (85°F) not exceeded. • Ammonia and other toxic pollutants (i.e., trace elements and organics): Acute or chronic criterion is not exceeded during any consecutive 3-year period.
Full Support but Threatened	• DO and pH: One or more criteria exceeded in 11 to 25% of the samples. • Temperature: Daily maximum criterion exceeded in <10% of the samples. • Ammonia and other toxic pollutants (i.e., trace elements and organics): Acute or chronic criterion exceeded once or twice during any consecutive 3-year period.
Non Support	• DO and pH: One or more criteria exceeded in >25% of the samples. • Temperature: Daily maximum criterion exceeded in >10% of the samples. • Ammonia and other toxic pollutants (i.e., trace elements and organics): Acute or chronic criterion exceeded three or more times during any consecutive 3-year period.

4.1.6.3.2 Assessment of Beneficial Use Support for Aquatic Life and Recreation Based on Lake Trophic Data

Trophic status is used to assess whether aquatic life and recreation use of a lake is impaired. Under the North Dakota use assessment methodology, it is assumed hypereutrophic lakes do not fully

support a sustainable sport fishery and are limited in recreational uses, whereas mesotrophic lakes fully support both aquatic life and recreation use. Eutrophic lakes may be assessed as fully supporting, fully supporting but threatened, or not supporting their uses for aquatic life or recreation. North Dakota further assesses eutrophic lakes based on: 1) the lake's water quality standards fishery classification; 2) information provided by North Dakota Game and Fish Department Fisheries Division staff, local water resource managers, and the public; 3) the knowledge of land use in the lake's watershed; and/or 4) the relative degree of eutrophication. For example, a eutrophic lake, which has a well-balanced sport fishery and experiences infrequent algal blooms, is assessed as fully supporting with respect to aquatic life and recreation use. A eutrophic lake, which experiences periodic algal blooms and limited swimming use, would be assessed as not supporting recreation use. A lake fully supporting its aquatic life and/or recreation use, but for which monitoring has shown a decline in its trophic status (i.e., increasing phosphorus concentrations over time), would be assessed as fully supporting but threatened.

Carlson's Trophic State Index (TSI) is used to assess lake trophic status. When conducting an aquatic life and recreation use assessment for a lake, the average TSI score should be calculated for each indicator (i.e., chlorophyll *a*, Secchi depth, and total phosphorus). If TSI scores for each indicator result in a different trophic status assessment, the assessment should be based first on the chlorophyll *a*, followed by the Secchi depth transparency. Only when there are not adequate chlorophyll *a* and/or Secchi depth data available to make an assessment should total phosphorus concentration data be used.

4.1.6.3.3 Assessment of Beneficial Use Support for Drinking Water

North Dakota's water quality standards define drinking water as "waters that are suitable for use as a source of water supply for drinking and culinary purposes, after treatment to a level approved by the North Dakota Department of Health. While most lakes and reservoirs are assigned this use, few currently are used as a drinking water supply; however, the District's Garrison Reservoir is used as a drinking water supply. Drinking water use is assessed by comparing ambient water quality data to the State water quality standards criteria for chloride, sulfate, nitrate, and to the defined human health criteria. The decision criteria used by North Dakota to make beneficial use determinations are given in Table 4.11.

Table 4.11. Drinking water use support decision criteria defined by North Dakota.

Aquatic Life Use Support	Criteria for Determining Use Support
Full Support	No exceedences of the water quality standard criterion for nitrate, one or fewer exceedences of the 30-day average criteria for chloride or sulfate, and no exceedences of any of the human health standards.
Full Support but Threatened	The fully supporting, but threatened use assessment designation is not applied to the drinking water use. Waters are either assessed as fully supporting or not supporting based on chemical data applied to the numeric standards.
Non Support	One or more exceedences of the water quality criterion for nitrate, two or more exceedences of the 30-day average criteria for chloride or sulfate, or one or more exceedences of any of the human health criteria.

4.1.6.4 South Dakota Assessment Methodologies

The State of South Dakota requires that beneficial use support determinations be based on sufficient and credible data. Data must meet QA/QC requirements that assure data are representative. The decision criteria regarding data age, sample size, and exceedences that the State of South Dakota uses to determine beneficial use support are given in Tables 4.12 through 4.14.

Table 4.12. Data age requirements specified by South Dakota to consider data representative of actual conditions.

Description	Criteria Used
CONVENTIONAL PARAMETRS (e.g., dissolved oxygen, total suspended solids, pH, temperature, fecal coliform bacteria, etc.) TOXIC PARAMETERS (e.g., metals, ammonia, etc.)	• STREAMS: Data must be less than 5 years old. • LAKES: Data collected after 1999. Unless there is justification that data is (or is not) representative of current conditions.
TOXIC PARAMETERS (e.g., metals, ammonia, etc.)	• STREAMS: At least one water quality sampling event.. • LAKES: At least one fish flesh sampling event.

Table 4.13. Sample size requirements specified by South Dakota to consider data representative of actual conditions.

Description	Criteria Used
CONVENTIONAL PARAMETERS (e.g., DO, TSS, pH, temperature, fecal coliform bacteria, etc.)	• STREAMS: At least 20 samples for any one parameter are usually required at any site. The sample threshold is reduced to 10 samples if >25% of samples exceed water quality standards criteria since impairment is more likely. In addition, the sample threshold is reduced to five samples if 100% of the samples indicate full or nonsupport for that parameter. • LAKES: Two separate years of samples for conventional and Trophic State Index (TSI) parameters. Must include at least one Secchi depth and chlorophyll *a* value. Sample dates must be between May 15 and September 15.
TOXIC PARAMETERS (e.g., metals, ammonia, etc.)	• STREAMS: At least one water quality sampling event.. • LAKES: At least one fish flesh sampling event.

Table 4.14. Decision criteria for beneficial use support determination identified by South Dakota.

Description	Use Support	Criteria
CONVENTIONAL PARAMETERS (e.g., DO, TSS, pH, temperature, fecal coliform bacteria, etc.)	Full Support	STREAMS: <10% of samples exceed criteria (<25% if less than 20 samples available). LAKES: <10% of surface samples (<25% if less than 20 samples available).
	Non Support	STREAMS: >10% of samples exceed criteria (>25% if less than 20 samples available). LAKES: >10% of surface samples (>25% if less than 20 samples available). If one surface exceedence was observed for water temperature, DO, or pH; lake profile data is used to make use support determination. Lakes are considered fully supporting the aquatic life beneficial use if profile data indicate a region within the water column where temperature, pH, and dissolved oxygen meet numeric water quality standards criteria. If a region does not exist, the lake is listed for the parameter in exceedence.

4.2 WATER QUALITY TRENDS

Surface water quality trends were assessed for water clarity (i.e. Secchi depth), total phosphorus, chlorophyll *a*, and calculated TSI(Avg) from monitoring results obtained at long-term, fixed-station ambient monitoring sites. Scatter plots were prepared by plotting the four parameters over the time period 1980 through 2008. A linear regression trend line was also plotted. Analysis of variance (ANOVA) was used to determine an R^2 value and to test for the significance ($\alpha = 0.05$) of a linear trend over time.

4.3 FISH TISSUE

Fish are capable of accumulating many toxic substances in excess of 1,000 times the concentrations found in surface waters. Subsequently, fish tissue analyses may provide information concerning the presence of toxicants in a waterbody that may not be detected through either water or sediment samples. Because of this, fish tissue monitoring is an excellent early indicator of potential toxic problems in surface waters. Different tissue types in fish (e.g., muscle, bone, organ, skin, adipose, etc.) tend to accumulate toxicants at different rates. Therefore, when used as an indicator, fish tissue analysis typically uses whole fish samples – a combination of all tissue types. The analysis of fish fillets for toxicants is typically used to determine the suitability of fish for human consumption. The public has expressed concerns on whether fish caught at District Projects are safe to consume. It is important that answers to public health concerns be based on substantiated knowledge of toxicants in fish fillets and the public health risks associated with measured toxicant concentrations. This type of information can be used by Tribes and States when considering the issuance of fish consumption advisories.

The District, at this time, does not collect fish tissue data at the Mainstem System Projects. However, all of the States in the District are currently implementing monitoring programs that include fish tissue sampling at the Mainstem System Projects. The District defers to the Tribes and States regarding ambient fish tissue monitoring and the issuance of fish consumption advisories. Advisories that have been issued by the appropriate Tribes and States and are in affect at the Mainstem System Projects are listed in Table 1.3.

5 MAINSTEM SYSTEM RESERVOIRS

5.1 BACKGROUND INFORMATION

The Mainstem System is comprised of six dams and reservoirs constructed by the Corps on the Missouri River and, where present, the free-flowing Missouri River downstream of the dams. The six dams and reservoirs in an upstream to downstream order are: Fort Peck Dam and Reservoir (MT), Garrison Dam and Reservoir (ND), Oahe Dam (SD) and Oahe Reservoir (ND and SD), Big Bend Dam and Reservoir (SD), Fort Randall Dam and Reservoir (SD), and Gavins Point Dam and Reservoir (NE and SD) (Figure 1.1). The authorized purposes for the six reservoirs include: flood control, recreation, fish and wildlife, hydroelectric power, water supply, water quality, navigation, and irrigation (Table 1.1). The six reservoirs impounded by the dams contain about 73.3 million acre-feet (MAF) of storage capacity and, at normal pool, an aggregate water surface area of about 1 million acres. Drought conditions in the upper Missouri River Basin in the early to mid-2000's reduced the water stored in the upper three Mainstem System reservoirs to record low levels. The water in storage at the all Mainstem System reservoirs at the end of 2008 (i.e., December 31, 2008) was 43.95 MAF, which is about 60 percent of the total Mainstem System storage volume. Table 5.1 gives selected engineering data for each of the six reservoirs

5.1.1 REGULATION OF THE MAINSTEM SYSTEM

The Mainstem System is a hydraulically and electrically integrated system that is regulated to obtain the optimum fulfillment of the multipurpose benefits for which the dams and reservoirs were authorized and constructed. The Congressionally authorized purposes of the Mainstem System are flood control, navigation, hydropower, water supply, water quality, irrigation, recreation, and fish and wildlife (including threatened and endangered species). The Mainstem System is operated under the guidelines described in the Missouri River Mainstem System Master Water Control Manual, (Master Manual) (USACE-RCC, 2006a). The Master Manual details regulation for all authorized purposes as well as emergency regulation procedures in accordance with the authorized purposes.

Mainstem System regulation is, in many ways, a repetitive annual cycle that begins in late winter with the onset of snowmelt. The annual melting of mountain and plains snow packs along with spring and summer rainfall produces the annual runoff into the Mainstem System. In a typical year, mountain snow pack, plains snow pack, and rainfall events respectively contribute 50, 25, and 25% of the annual runoff to the Mainstem System. After reaching a peak, usually during July, the amount of water stored in the Mainstem System declines until late in the winter when the cycle begins anew. A similar pattern may be found in rates of releases from the Mainstem System, with the higher levels of releases from mid-March to late-November, followed by low rates of winter discharge from late-November until mid-March, after which the cycle repeats.

To maximize the service to all of the authorized purposes, given the physical and authorization limitations of the Mainstem System, the total storage available in the Mainstem System is divided into four regulation zones that are applied to the individual reservoirs. These four regulation zones are: 1) Exclusive Flood Control Zone, 2) Annual Flood Control and Multiple Use Zone, 3) Carryover Multiple Use Zone, and 4) Permanent Pool Zone.

Table 5.1. Summary of selected engineering data for the Missouri River Mainstem System.

	Fort Peck	Garrison	Oahe	Big Bend	Fort Randall	Gavins Point
General						
Lake Name	Fort Peck Lake	Lake Sakakawea	Lake Oahe	Lake Sharpe	Lake Francis Case	Lewis and Clark Lake
River Mile (1960 Mileage)	1771 5	1389 9	1072 3	987 4	880 0	811 1
Total and Incremental Drainage Area (square miles)	57,500	181,400 123,900	243,490 62,900	249,330 5,840	263,480 145,150	279,480 16,000
Reservoir Length at Top of Carryover Multiple Use Pool (miles)	134	178	231	80	107	25
Shoreline Length at Top of Carryover Multiple Use Pool (miles)	1,520	1,340	2,250	200	540	90
Top Elevation of Carryover Multiple Use Pool (ft-msl)	2234 0	1837 5	1607 5	1422 0	1350 0	1208 0
Year Storage First Available for Regulation of Flows	1940	1955	1962	1964	1953	1955
Original Conditions ("As-Built")						
Surface Area of Carryover Multiple Use Pool (acres)	214,718	322,030	314,649	59,150	82,000	31,100
Capacity of Carryover Multiple Use Pool (acre-feet)	15,869,000	18,917,000	19,490,000	1,920,000	3,911,000	510,000
Mean Depth at top of Carryover Multiple Use Pool[(1)] (feet)	73 9	58 7	61 9	32 5	47 7	16 4
Most Recent Surveyed Conditions	2007 (USACE)	1988 (USACE)	1989 (USACE)	1997 (USACE)	1996 (USACE)	2007 (USACE)
Surface Area at top of Carryover Multiple Use Pool (acres)	210,700	307,400	312,100	59,700	76,700	26,900
Capacity of Carryover Multiple Use Pool (acre-feet)	14,788,000	18,110,000	18,834,000	1,738,000	3,124,000	393,000
Mean Depth at top of Multiple Use Pool[(1)] (feet)	70 2	58 9	60 3	29 1	40 7	14 6
Sediment Deposition to Top of Carryover Multiple Use Pool						
Surveyed Sediment Deposition[(2)] (acre-feet)	1,081,000	807,000	656,000	182,000	787,000	117,000
Annual Sedimentation Rate[(3)] (acre-feet/year)	16,140	24,460	24,300	5,520	18,310	2,250
Current Estimated Sediment Deposition[(4)] (acre-feet)	1,097,100	1,296,200	1,117,700	242,700	1,006,700	119,300
Current Capacity of Carryover Multiple Use Pool[(5)] (acre-feet)	14,772,000	17,621,000	18,373,000	1,678,000	2,905,000	390,700
Estimated Carryover Multiple Use Pool Capacity Lost through 2008	6 9%	6 9%	5 7%	12 6%	25 7%	23 4%
Operational Details – Historic (1967 through 2008)						
Maximum Recorded Pool Elevation (ft-msl)	2251 6	1854 8	1618 7	1422 1	1372 2	1209 5
Minimum Recorded Pool Elevation (ft-msl)	2196 5	1805 8	1570 2	1414 9	1317 9	1199 8
Average Daily Pool Elevation (ft-msl)	2229 6	1834 4	1601 0	1420 4	1351 1	1206 8
Maximum Recorded Daily Inflow (cfs)	160,000	180,000	204,000	79,000	100,000	74,000
Maximum Recorded Daily Outflow (cfs)	1,000	1,000	5,000	100	100	70,100
Average Annual Inflow (ac-ft)	7,246,000	16,248,000	17,950,000	17,113,000	18,009,000	19,739,000
Average Annual Outflow (ac-ft)	6,709,000	15,426,000	17,147,000	16,937,000	17,741,000	19,643,000
Operational Details – Current (2008)						
Maximum Recorded Pool Elevation (ft-msl)	2210 3	1826 4	1594 3	1421 1	1362 1	1208 5
Minimum Recorded Pool Elevation (ft-msl)	2198 4	1807 3	1581 6	1419 4	1337 0	1205 0
Maximum Recorded Daily Inflow (cfs)	46,000	82,000	103,000	26,000	50,000	28,000
Maximum Recorded Daily Outflow (cfs)	8,800	16,200	31,400	30,900	1,000	25,500
Total Inflow (% of Average Annual)	6,376,000 ac-ft (88%)	13,765,000 ac-ft (85%)	11,802,000 ac-ft (66%)	8,056,000 (47%)	9,091,000 (50%)	10,747,000 (54%)
Total Outflow (% of Average Annual)	4,269,000 ac-ft (64%)	9,595,000 ac-ft (62%)	8,524,000 ac-ft (50%)	7,876,000 (47%)	8,990,000 (51%)	10,630,000 (54%)
Power Tunnel Entrance Invert Elevation	2095 ft-msl (65 feet above bottom)	1672 ft-msl (2 feet above bottom)	1525 ft-msl (110 feet above bottom)	1330 ft-msl (Bottom)	1229 ft-msl (2 feet above bottom)	1139 5 ft-msl (Bottom)

Note: All elevations given are in the NGVD 29 datum
(1) Mean Depth = Volume ÷ Surface Area
(2) Surveyed sediment deposition is the difference in reservoir storage capacity to top of Carryover Multipurpose Use Pool between "as-built" and survey
(3) Annualized rate based on historic accumulated sediment
(4) Accumulated sediment through 2008 estimated from historic annual sedimentation rate
(9) Current capacity of Multipurpose Pool = "As-Built" Multipurpose Pool capacity - Estimated Current Sedimentation

5.1.1.1 Exclusive Flood Control Zone

Flood control is the only authorized purpose that requires empty space in the reservoirs to achieve the objective. A top zone in each Mainstem System reservoir is reserved for use to meet the flood control requirements. This storage space is used only for detention of extreme or unpredictable flood flows and is evacuated as rapidly as downstream conditions permit, while still serving the overall flood control objective of protecting life and property. The Exclusive Flood Control Zone encompasses 4.7 MAF and represents the upper 6 percent of the total Mainstem System storage volume. This zone, from 73.3 MAF down to 68.7 MAF, is normally empty. The four largest reservoirs, Fort Peck, Garrison, Oahe, and Fort Randall, contain 97 percent of the total storage reserved for the Exclusive Flood Control Zone.

5.1.1.2 Annual Flood Control and Multiple Use Zone

An upper "normal operating zone" is reserved annually for the capture and retention of runoff (normal and flood) and for annual multiple-purpose regulation of this impounded water. The Mainstem System storage capacity in this zone is 11.7 MAF and represents 16 percent of the total Mainstem System storage. This storage zone, which extends from 68.7 MAF down to 57.0 MAF, will normally be evacuated to the base of this zone by March 1 to provide adequate storage capacity for capturing runoff during the next flood season. On an annual basis, water will be impounded in this zone, as required to achieve the Mainstem System flood control purpose and also be stored in the interest of general water conservation to serve all the other authorized purposes. The evacuation of water from the Annual Flood Control and Multiple Use Zone is scheduled to maximize service to the authorized purposes that depend on water from the Mainstem System. Scheduling releases from this zone is limited by the flood control objective in that the evacuation must be completed by the beginning of the next flood season. This is normally accomplished as long as the evacuation is possible without contributing to serious downstream flooding. Evacuation is, therefore, accomplished mainly during the summer and fall because Missouri River ice formation and the potential for flooding from higher release rates limit release rates during the December through March period.

5.1.1.3 Carryover Multiple Use Zone

The Carryover Multiple Use Zone is the largest storage zone extending from 57.0 MAF down to 18.0 MAF, and represents 53 percent of the total Mainstem System storage volume. Serving the authorized purposes during an extended drought is an important regulation objective of the Mainstem System. The Carryover Multiple Use Zone provides a storage reserve to support authorized purposes during drought conditions. Providing this storage is the primary reason the upper three reservoirs of the Mainstem System are so large compared to other Federal water resource projects. The Carryover Multiple Use Zone is often referred to as the "bank account" for water in the Mainstem System because of its role in supporting authorized purposes during critical dry periods when the storage in the Annual Flood Control and Multiple Use Zone is exhausted. Only the reservoirs at Fort Peck, Garrison, Oahe, and Fort Randall have this storage as a designated storage zone. The three larger reservoirs (Fort Peck, Garrison, and Oahe) provide water to the Mainstem System during drought periods to provide for authorized purposes. The storage space assigned to this zone in Fort Randall Reservoir serves a different purpose. It is normally evacuated each year during the fall season to provide recapture space for upstream winter power releases. The recapture results in complete refill of Fort Randall Reservoir during the winter months. During drought periods, the three smaller projects (Fort Randall, Big Bend, and Gavins Point) reservoir levels are maintained at the same elevation they would be at if runoff conditions were normal.

5.1.1.4 <u>Permanent Pool Zone</u>

The Permanent Pool Zone is the bottom zone that is intended to be permanently filled with water. The zone provides for future sediment storage capacity and maintenance of minimum pool levels for power heads, irrigation diversions, water supply, recreation, water quality, and fish and wildlife. A drawdown into this zone will generally not be scheduled except in unusual conditions. The Mainstem System storage capacity in this storage zone is 18.0 MAF and represents 25 percent of the total storage volume. The Permanent Pool Zone extends from 18.0 MAF down to 0 MAF.

5.1.2 WATER CONTROL PLAN FOR THE MAINSTEM SYSTEM

Variations in runoff into the Mainstem System necessitates varied regulation plans to accommodate the multipurpose regulation objectives. The two primary high-risk flood seasons are the plains snowmelt and rainfall season extending from late February through April, and the mountain snowmelt and rainfall period extending from May through July. Also, the winter ice-jam flood period, which extends from mid-December through February, can be a high-risk flood period. The highest average power generation period extends from mid-April to mid-October, with high peaking loads during the winter heating season (mid-December to mid-February) and the summer air conditioning season (mid-June to mid-August). The power needs during the winter are supplied primarily with Fort Peck and Garrison Dam releases and the peaking capacity of Oahe and Big Bend Dams. During the spring and summer period, releases are normally geared to navigation and flood control requirements, and primary power loads are supplied using the four lower dams. During the fall when power needs diminish, Fort Randall is normally drawn down to permit generation during the winter period when Oahe and Big Bend peaking-power releases refill the reservoir. The normal 8-month navigation season extends from April 1 through November 30, during which time Mainstem System releases are increased to meet downstream target flows in combination with downstream tributary inflows. Winter releases after the close of the navigation season are much lower and vary depending on the need to conserve or evacuate storage volumes, downstream ice conditions permitting. Releases and pool fluctuations for fish spawning management generally occur from April 1 through June. Two threatened and endangered bird species, piping plover (*Charadrius melodus*) and least tern (*Sterna antillarum*), nest on "sandbar" areas from early May through mid-August. Other factors may vary widely from year to year, such as the amount of water-in-storage and the magnitude and distribution of inflow received during the coming year. All these factors will affect the timing and magnitude of Mainstem System releases. The gain or loss in the water stored at each reservoir must also be considered in scheduling the amount of water transferred between reservoirs to achieve the desired storage levels and to generate power. These items are continually reviewed as they occur and are appraised with respect to the expected range of regulation.

5.1.3 OCCURRENCE OF "TWO-STORY" FISHERIES

Fort Peck, Garrison, and Oahe Reservoirs maintain "two-story" fisheries that are comprised of warmwater and coldwater species. The ability of the reservoirs to maintain "two-story" fisheries is due to their thermal stratification in the summer into a colder bottom region and a warmer surface region. Warmwater species present in the reservoirs that are recreationally important include walleye (*Sander vitreus*), sauger (*Sander canadensis*), northern pike (*Esox lucius*), smallmouth bass (*Micropterus dolomieu*), catfish (*Ictalurus spp.*), and yellow perch (*Perca flavescens*). Coldwater species of recreational importance are the Chinook salmon (*Oncorhynchus tshawytscha*) and lake trout (*Salvelinus namaycush*). Chinook salmon are maintained in all three reservoirs through regular stocking, and lake trout are present in Fort Peck Reservoir. Other coldwater species present are rainbow smelt (*Osmerus mordax*) in Oahe and Garrison Reservoirs and lake cisco (*Coregonus artedi*) in Fort Peck Reservoir. Both these species are important forage fish that are utilized extensively by all recreational species in the

respective reservoirs. Maintaining healthy populations of these coldwater forage fish are important to maintaining the recreational fisheries in the three reservoirs.

The occurrence of coldwater habitat in Fort Peck, Garrison, and Oahe Reservoirs is directly dependent on each reservoir's annual thermal regime. Early in the winter ice-cover period, the entire reservoir volume will be supportive of coldwater habitat. As the winter ice-cover period continues, lower dissolved oxygen concentrations will likely occur near the bottom as organic matter decomposes and reservoir mixing is prevented by ice cover. As dissolved oxygen concentrations in the near-bottom water fall below 5 mg/l, coldwater habitat will not be supported. During the spring isothermal period, water temperatures and dissolved oxygen levels in the entire reservoir volume will be supportive of coldwater habitat. During the early-summer warming period, the epilimnion will become non-supportive of coldwater habitat. During mid-summer when the reservoirs are experiencing maximum thermal stratification, water temperatures will only be supportive of coldwater habitat in the hypolimnion. Theoretically, coldwater habitat should remain stable during this period unless degradation of dissolved oxygen concentrations near the reservoir bottom becomes non-supportive of coldwater habitat. The most crucial period for the support of coldwater habitat in the three reservoirs is when they begin to cool in late summer. As the thermocline moves deeper, the volume of the coldwater hypolimnion will continue to decrease while the expanding epilimnion may not yet be cold enough to be supportive of coldwater habitat. At the same time, hypolimnetic dissolved oxygen concentrations are approaching their maximum degradation and low dissolved oxygen levels are moving upward from the reservoir bottom and pinching off coldwater habitat from below. This situation will continue to worsen until the epilimnion cools enough to be supportive of coldwater habitat. When fall turnover occurs, dissolved oxygen concentrations at all depths will be near saturation and supportive of coldwater habitat. However, depending on the conditions of the reservoir, the isothermal temperature at the beginning of fall turnover may not be supportive of all coldwater habitats. This situation will continue to occur until the isothermal temperature cools to a suitable temperature, at which time the entire reservoir volume will be supportive of coldwater habitat.

5.2 FORT PECK

5.2.1 BACKGROUND INFORMATION

5.2.1.1 <u>Project Overview</u>

Fort Peck Dam is located on the Missouri River at river mile (RM) 1771.5 in northeastern Montana, 17 miles southeast of Glasgow, MT. The closing of Fort Peck Dam in 1937 resulted in the formation of Fort Peck Reservoir (Fort Peck Lake). When full, the reservoir is 134 miles long, covers 246,000 acres, and has 1,520 miles of shoreline. Table 5.2 summarizes how the surface area, volume, mean depth, and retention time of Fort Peck Reservoir vary with pool elevations. Although still experiencing lower pool levels due to ongoing drought conditions, the reservoir did recover to a pool elevation of 2210.0 at the end of December 2008. This is 10.5 feet higher than the reservoir was 1-year ago at the end of 2007. At a pool elevation of 2210.0 ft-msl, Fort Peck Reservoir is 24 feet below the top of the Carryover Multiple Use Zone (2234.0 ft-msl). Major inflows to the reservoir come from the Missouri River, Musselshell River, and Big Dry Creek. Water discharged through Fort Peck Dam for power production is withdrawn from Fort Peck Reservoir at elevation 2095 ft-msl – approximately 65 feet above the reservoir bottom.

Table 5.2. Surface area, volume, mean depth, and retention time of Fort Peck Reservoir at different pool elevations based on 2007 survey.

Pool Elevation (Feet-msl)	Surface Area (Acres)	Volume (Acre-Feet)	Mean Depth (Feet)*	Retention Time (Years)**
2250	245,405	18,462,840	75.2	2.55
2245	237,605	17,253,500	72.6	2.38
2240	225,065	16,094,980	71.5	2.22
2235	213,025	15,000,180	70.4	2.07
2230	201,130	13,964,500	69.4	1.93
2225	188,765	12,991,390	68.8	1.79
2220	180,590	12,069,610	66.8	1.67
2215	171,930	11,188,080	65.1	1.54
2210	163,400	10,349,820	63.3	1.43
2205	154,773	9,554,578	61.7	1.32
2200	146,595	8,801,156	60.0	1.21
2195	138,081	8,090,417	58.6	1.12
2190	132,175	7,415,889	56.1	1.02
2185	126,146	6,769,319	53.7	0.93
2180	118,608	6,156,918	51.9	0.85
2175	111,285	5,582,093	50.2	0.77
2170	103,394	5,045,002	48.8	0.70
2165	95,316	4,549,151	47.7	0.63
2160	89,461	4,087,903	45.7	0.56

Average Annual Inflow (1967 through 2008) = 7.246 Million Acre-Feet
Average Annual Outflow: (1967 through 2008) = 6.709 Million Acre-Feet
* Mean Depth = Volume ÷ Surface Area.
** Retention Time = Volume ÷ Average Annual Outflow.
Note: Exclusive Flood Control Zone (elev. 2250-2246 ft-msl), Annual Flood Control and Multiple Use Zone (elev. 2246-2234 ft-msl), Carryover Multiple Use Zone (elev. 2234-2160 ft-msl), and Permanent Pool Zone (elev. 2160-2030 ft-msl). All elevations are in the NGVD 29 datum.

Fort Peck was authorized for the purposes of flood control, recreation, fish and wildlife, hydroelectric power production, water supply, water quality, navigation, and irrigation. Over the period 1967 through 2008, the five generating units at Fort Dam have produced an annual average 1.064 million mega-watt hours (MWh) of electricity, which has a current revenue value of approximately $17 million. The ongoing drought in the western United States has curtailed releases and power production at the Mainstem System projects, including Fort Peck. Power production at the Fort Peck Dam generating units averaged an annual 0.641 MWh over the 5-year period 2004 through 2008. Habitat for one endangered species, pallid sturgeon (*Scaphirhynchus albus*), occurs within the project area. The reservoir is used as a water supply by the town of Fort Peck, MT and by numerous individual cabins in the area. Fort Peck Reservoir is an important recreational resource and a major visitor destination in Montana.

5.2.1.2 <u>Water Quality Standards Classifications and Section 303(d) Listings</u>

5.2.1.2.1 Fort Peck Reservoir

The State of Montana has assigned Fort Peck Reservoir a B-3 classification in the State's water quality standards. The reservoir is to be maintained suitable for drinking, culinary, and food processing purposes, after conventional treatment; bathing, swimming, and recreation; growth and propagation of non-salmonid fishes and associated aquatic life, waterfowl, and furbearers; and agricultural and industrial water supply. Pursuant to Section 303(d) of the Federal CWA, Montana has placed Fort Peck Reservoir

on the State's list of impaired waters citing impairment to the uses of drinking water supply and recreation. The impairment of drinking water is attributed to the pollutants of lead and mercury, and the impairment of recreation is attributed to native aquatic plants. The identified sources of these pollutants are agriculture, abandoned mining, atmospheric deposition, and historic bottom deposits. The State of Montana has also issued a fish consumption advisory for Fort Peck Reservoir due to mercury concerns.

5.2.1.2.2 Missouri River Downstream of Fort Peck Dam

The Missouri River downstream of Fort Peck Dam has been designated a B-2 classification from the dam to the confluence of the Milk River, and a B-3 classification from the Milk River confluence to the Montana/North Dakota state line (Montana water quality standards). Both B-2 and B-3 waters are to be maintained suitable for drinking, culinary, and food processing purposes, after conventional treatment; bathing, swimming, and recreation; waterfowl and furbearers; and agricultural and industrial water supply. In addition, B-2 waters are to maintain growth and marginal propagation of salmonid fishes and associated aquatic life, and B-3 waters are to maintain growth and propagation of non-salmonid fishes and associated aquatic life. The river is used as a water supply by several towns along the reach. Pursuant to Section 303(d) of the Federal CWA, Montana has placed the Missouri River downstream of Fort Peck Dam on the State's list of impaired waters citing impairment to the uses of aquatic life support, coldwater fishery, and warmwater fishery due to the stressors of flow alteration, riparian alteration, and water temperature. The identified probable sources of these stressors are dam/impoundment, impacts from hydro structure, flow regulation/modification, and loss of riparian habitat. No fish consumption advisory has been issued for the Missouri River downstream of Fort Peck Dam by the State of Montana.

The Assiniboine and Sioux Tribes of the Fort Peck Indian Reservation have developed water quality standards, approved by the U.S. Environmental Protection Agency, that are applicable to their tribal lands. This includes an area on the north side of the Missouri River downstream of Fort Peck Dam from the Milk River to Big Muddy Creek. The tribal water quality standards applicable to this reach of the Missouri River are comparable to the State of Montana's water quality standards.

5.2.1.3 Water Quality for the Enhancement of Pallid Sturgeon Populations in the Missouri River Downstream of Fort Peck Dam

One of the few remaining populations of pallid sturgeon occurs in the Missouri River between Fort Peck Dam and the headwaters of Garrison Reservoir. Individuals in this population also inhabit the lower Yellowstone River. As such, this reach of the Missouri River has been identified as a priority recovery area for the pallid sturgeon (USFWS, 1993). It is believed that the building and operation of Fort Peck Dam and Reservoir have adversely impacted the pallid sturgeon in this reach of the Missouri River by regulating flows, lowering water temperatures, reducing sediment and nutrient transport, and increasing water clarity.

Historically, the lower Missouri River in Montana was a turbid, warmwater environment with seasonally fluctuating flows. The sediment and turbidity of the water through these cycles contributed significantly to the evolution of the pallid sturgeon. The fish adapted to highly turbid and low visibility environments by physiologically evolving to enhance their ability to capture prey and avoid capture as juveniles and larvae in this low visibility environment. It is also believed that the pallid sturgeon adapted by developing spawning cues based on historical conditions in the river. The fish requires a spawning cue of suitable magnitude, duration, and timing to complete this life cycle element. It is believed that increasing flow and water temperature in the late spring is a primary factor for pallid sturgeon to initiate spawning.

Water temperature is believed to be a controlling factor on the pallid sturgeon in this reach of the Missouri River in regards to spawning cues and larval survival during the summer. Because Fort Peck Dam has a deepwater withdrawal from the reservoir, water temperature in the Missouri River downstream of the dam are appreciably colder than "pre-dam" conditions. A water temperature of around 18°C (64.4°F) is believed necessary to initiate a spawning response in pallid sturgeon. Additionally, a dramatic decline in water temperatures after spawning can affect larval pallid sturgeon development and likely adversely affect the production and availability of suitable forage (i.e., plankton and other invertebrate species) for the juvenile pallid sturgeon throughout the summer. Low water temperatures may induce mortality in young pallid sturgeon. With this in mind, a late-spring/early-summer water temperature of 18°C in the Missouri River at Frazer Rapids (approximately 25 miles downstream of Fort Peck Dam) has been identified as critical for pallid sturgeon spawning and recruitment in this reach of the river.

Fort Peck Reservoir is trapping sediment that historically moved down the Missouri River past Fort Peck Dam. It is also believed that the current colder water temperatures in the river downstream of the dam are likely suppressing production of plankton and other invertebrate organisms that contribute to turbidity of the water. The resulting clearer water is believed to adversely affect young pallid sturgeon by making them more vulnerable to sight-feeding predators and increasing competition for food by sight-adapted predators. In addition, adult fish may be adversely affected by the increased ability of prey to avoid capture in clearer water.

5.2.1.4 <u>Ambient Water Quality Monitoring</u>

The District has monitored water quality conditions at the Fort Peck Project since the late 1970's. Water quality monitoring locations have included sites on the reservoir and on the inflow to and outflow from the reservoir. A 3-year intensive water quality survey was completed at the Fort Peck Project in 2006, and the findings of the intensive survey are available in the separate report, "Water Quality Conditions Monitored at the Corps' Fort Peck Project in Montana during the 3-Year period 2004 through 2006" (USACE, 2007a). Other recent water quality reports concerning the Fort Peck Project include: "Simulation of Fort Peck Lake Temperature Releases and Downstream Missouri River Temperatures" (USACE, 2007b), and "Fort Peck Temperature Control Device Reconnaissance Study Fort Peck, Montana" (Tetra Tech, 2009). Figure 5.1 shows the location of sites at the Fort Peck Project that have been monitored by the District for water quality during the past 5 years (i.e., 2004 through 2008). The near-dam location (i.e., site FTPLK1772A) has been continuously monitored since 1980.

5.2.2 WATER QUALITY IN FORT PECK RESERVOIR

5.2.2.1 <u>Existing Water Quality Conditions (2004 through 2008)</u>

5.2.2.1.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

Water quality conditions that were monitored in Fort Peck Reservoir at sites FTPLK1772A, FTPLK1778DW, FTPLK1789DW, FTPLK1805DW, FTPLKBDCA01, and FTPLKBDCA02 from May through September during the 5-year period 2004 through 2008 are summarized in Plates 1 through 6. A review of these results found no significant water quality concerns. On a few occasions measured dissolved oxygen concentrations were below the water quality standards criterion of 5 mg/l for the protection of Class B-3 warmwater aquatic life in the mid-reaches of the Missouri River Arm (Plates 3 and 4). The measured low dissolved oxygen concentrations occurred in the hypolimnion near the reservoir bottom during the later part of the summer thermal stratification period. The lowest dissolved oxygen concentration measured was 2.2 mg/l and occurred at site FTPLK1789DW on August 30, 2006.

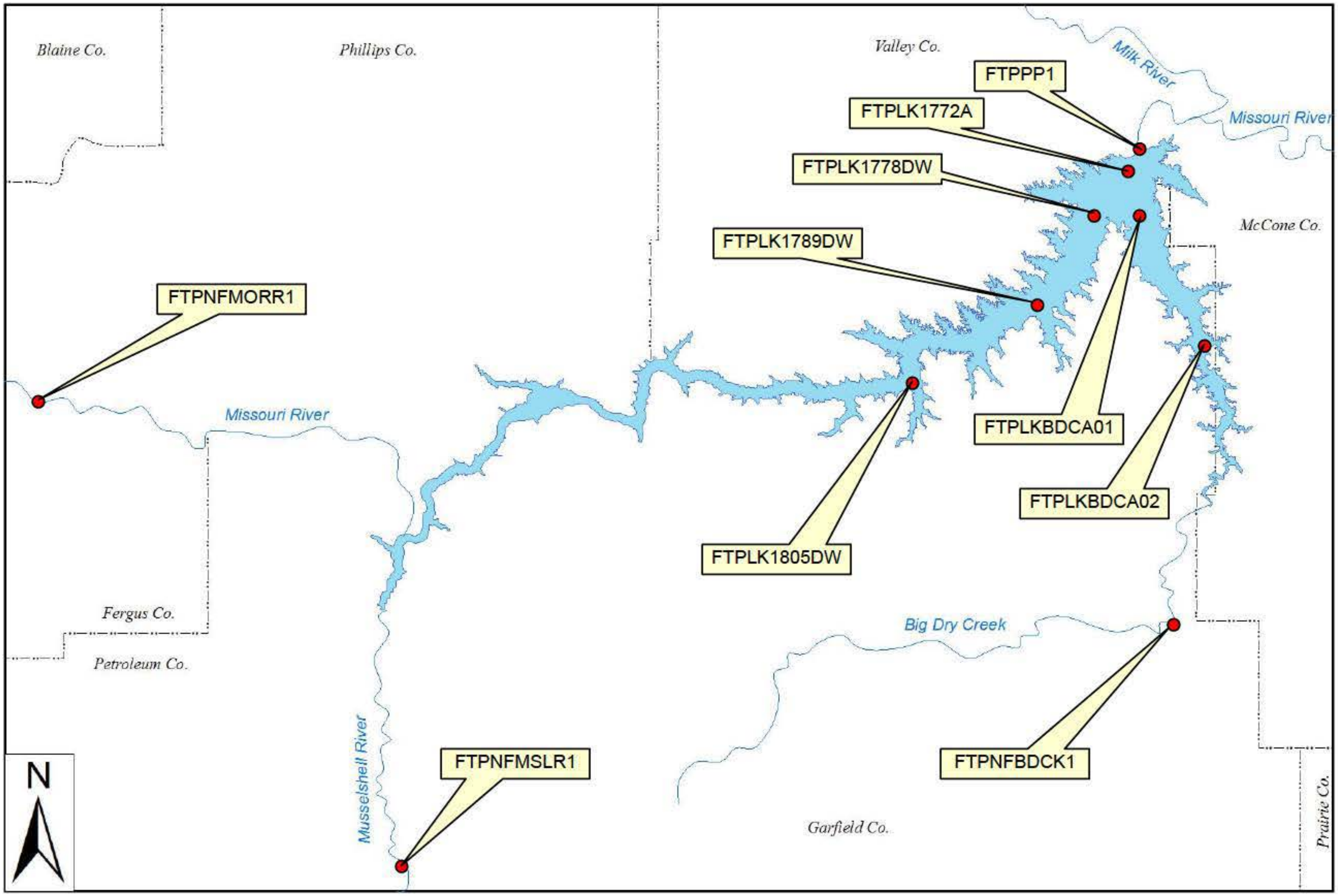

Figure 5.1. Location of sites where water quality monitoring was conducted by the District at the Fort Peck Project during the 5-year period 2004 through 2008.

5.2.2.1.2 Summer Thermal Stratification

5.2.2.1.2.1 2008 Monthly Longitudinal Temperature Contour Plots

Late-spring and summer thermal stratification of Fort Peck Reservoir during 2008 is described by longitudinal temperature contour plots based on depth-profile temperature measurements taken during May, June, August, and September (Plates 7-10). The contour plots were constructed along two longitudinal axes; the Missouri River mainstem arm and the Big Dry Creek arm. As seen in Plates 7 through 10, temperatures in Fort Peck Reservoir vary longitudinally from the dam to the Missouri River inflow and vertically from the reservoir surface to the bottom. The near-surface water in the upstream reach of the reservoir warms up sooner in the spring than the near-surface water near the dam (Plates 7 and 8). By mid-summer a strong thermocline becomes established in the downstream reach of the reservoir, and the near-surface waters of the entire reservoir above the thermocline are a fairly uniform temperature (Plate 9). As the near-surface waters of the reservoir cool in the late summer, the thermocline moves deeper, and the wind-mixed upper waters are fairly uniform in temperature (Plate 10). The vertical variation in temperature is most prevalent in the deeper area of the reservoir towards the dam, where a strong thermocline becomes established during the summer. The shallower upper reaches of Fort Peck Reservoir do not exhibit much vertical variation of temperature during mid- to late summer, as wind action allows for complete mixing of the water column.

5.2.2.1.2.2 Near-Dam Temperature Depth-Profile Plots

Existing summer thermal stratification of Fort Peck Reservoir at the deep water area near the dam is described by the depth-profile temperature plots measured over the past 5 years. Depth-profile temperature plots measured during the summer were compiled (Plate 11). The plotted depth-profile measurements indicate that a significant temperature-depth gradient occurs in Fort Peck Reservoir in the near-dam lacustrine area during the summer, and a thermocline becomes established at a depth of about 20 meters (Plate 11).

5.2.2.1.3 Summer Dissolved Oxygen Conditions

5.2.2.1.3.1 2008 Monthly Longitudinal Dissolved Oxygen Contour Plots

Late-spring and summer dissolved oxygen conditions in Fort Peck Reservoir during 2008 are described by the monthly longitudinal dissolved oxygen contour plots based on depth-profile temperature measurements taken in May, June, August, and September (Plates 12-15). The contour plots were constructed along two longitudinal axes; the Missouri River mainstem arm and the Big Dry Creek Arm. As seen in Plates 12 through 15, dissolved oxygen conditions in Fort Peck Reservoir vary longitudinally from the dam to the reservoir's upstream reaches and vertically from the reservoir surface to the bottom. Dissolved oxygen levels below 5 mg/l first appeared near the reservoir bottom in the middle reaches of the Missouri River Arm in August (Plates 14). The lowest dissolved oxygen concentrations remained in this area of the reservoir through fall turnover (Plates 15). Near-bottom dissolved oxygen concentrations near the dam remained above 5 mg/l. The earlier occurrence of low dissolved oxygen concentrations in the near-bottom water of the middle reaches of Fort Peck Reservoir is attributed to the increased organic loading (allochthonous and autochthonous) in the transition zone of the reservoir and the lesser hypolimnetic volume available for assimilation of the oxygen demand. As this material decomposes, a "pool" of water with lower dissolved oxygen levels accumulates near the bottom in this area of the reservoir. Decomposition of autochthonous organic matter also occurs in the lacustrine zone and results in dissolved oxygen degradation as the summer progresses, although at a slower rate than what occurs in the transition zone. The recovery of near-bottom dissolved oxygen concentrations to saturation levels takes longer in the lacustrine zone nearer the dam because of the time needed for thermal stratification to breakdown and mixing within the water column to occur in the deeper water.

5.2.2.1.3.2 Near-Dam Dissolved Oxygen Depth-Profile Plots

Existing summer dissolved oxygen conditions in Fort Peck Reservoir at the deep water area near the dam is described by the depth-profile dissolved oxygen plots measured over the past 5 years. Depth-profile dissolved oxygen plots measured during the summer were compiled (Plate 16). Dissolved oxygen levels did not exhibit a large gradient with depth and tended toward an orthograde to slight clinograde vertical distribution (Plate 16). During the period of 2004 through 2008, monitored dissolved oxygen concentrations in the hypolimnion remained above 5 mg/l through the summer (Plate 16).

5.2.2.1.4 Water Clarity

5.2.2.1.4.1 Secchi Transparency

Figure 5.2 displays a box plot of the Secchi depth transparencies measured at monitoring sites FTPLK1772A, FTPLK1805DW, and FTPLKBDCA02 during the period 2004 through 2008. Secchi depth transparency was observably lower in the upper reaches of both arms of the reservoir (i.e., sites FTPLK1805DW and FTPLKBDCA02) as compared to the near-dam conditions (i.e., site FTPLK1772A).

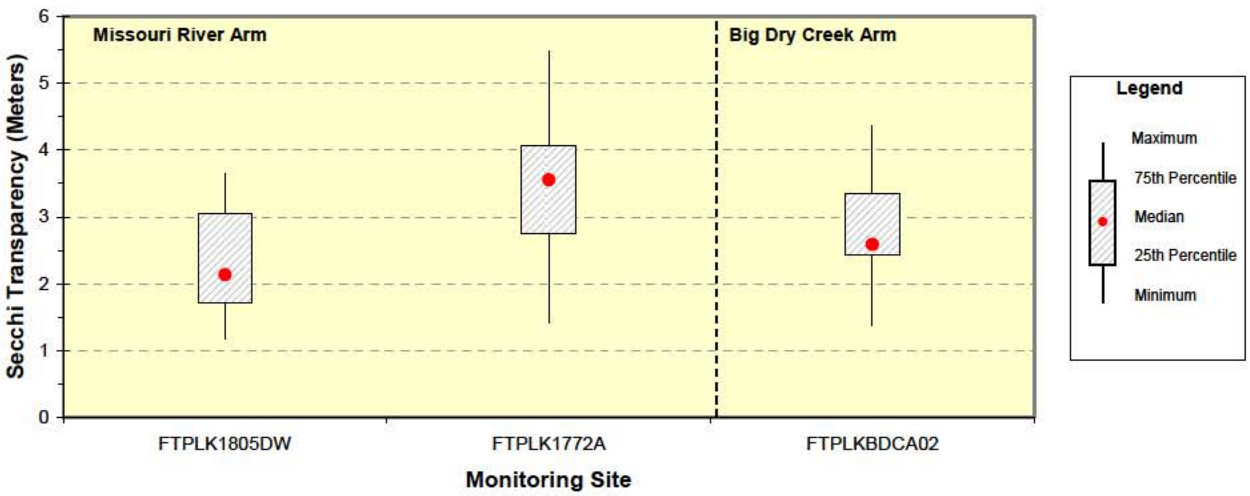

Figure 5.2. Box plot of Secchi transparencies measured in Fort Peck Reservoir during the period 2004 through 2008.

5.2.2.1.4.2 Turbidity

Turbidity is an expression of the optical property that causes light to be scattered and absorbed rather than transmitted with no change in direction or flux level. Turbidity in water is caused by suspended and colloidal matter such as clay, silt, finely divided organic and inorganic matter, plankton, and other microscopic organisms. Given the low chlorophyll *a* concentrations monitored in Fort Peck Reservoir (Plates 1-6), turbidity in the reservoir appears to be largely due to suspended inorganic material. Monthly (i.e., June, August, and September) longitudinal contour plots were prepared from the depth-profile turbidity measurements taken at sites FTPLK1772A, FTPLK1805DW, FTPLKBDCA02, and, FTPNFMORR1 during 2008 (Plates 17 - 19). As seen in Plates 17 through 20, turbidity levels in Fort Peck Reservoir vary longitudinally from the dam to reservoir's upstream reaches and vertically from the reservoir surface to the bottom. Turbidity levels are noticeably higher in the upstream reaches of the Missouri River Arm of the reservoir as compared to the area near the dam. This is attributed to the turbid conditions of the inflowing Missouri River.

5.2.2.1.5 Comparison of Near-Surface and Near-Bottom Water Quality Conditions

Paired near-surface and near-bottom water quality samples collected from Fort Peck Reservoir during the summer were compared. Near-surface conditions were represented by samples collected within 2-meters of the reservoir surface, and near-bottom conditions were represented by samples collected within 2-meters of the reservoir bottom. The compared samples were collected at the near-dam site FTPLK1772A during the 5-year period 2004 through 2008. During the period a total of 19 paired samples were collected monthly from June through September. Box plots were constructed to display the distribution of the paired near-surface and near-bottom measurements for the following parameters: water temperature, dissolved oxygen, oxidation-reduction potential (ORP), pH, alkalinity, total organic carbon (TOC), total Kjeldahl nitrogen (TKN), total ammonia, and total phosphorus (Plate 20). A paired two-tailed t-test was used to determine if the sampled near-surface and near-bottom conditions for the paired samples were significantly different ($\alpha = 0.05$). The sampled near-surface and near-bottom conditions were significantly different for all the assessed parameters except TKN, total ammonia, and total phosphorus. Parameters that were significantly lower in the near-bottom water of Fort Peck Reservoir included: water temperature ($p < 0.001$), dissolved oxygen ($p < 0.01$), pH ($p < 0.001$), and TOC ($p < 0.05$). Parameters that were significantly higher in the near-bottom water included: ORP ($p < 0.001$) and alkalinity ($p < 0.001$).

5.2.2.1.6 Reservoir Trophic Status

Trophic State Index (TSI) values for Fort Peck Reservoir were calculated from monitoring data collected during the 5-year period 2004 through 2008 (Table 5.3). The calculated TSI values indicate that the regions of the reservoir represented by the monitored sites are in a mesotrophic state.

Table 5.3. Mean Trophic State Index (TSI) values calculated for three sites on Fort Peck Reservoir based on monitoring conducted during the 5-year period 2004 through 2008.

Monitoring Site	Mean – TSI (Secchi Depth)	Mean – TSI (Total Phos.)	Mean – TSI (Chlorophyll)	Mean – TSI (Average)
FTPLK1772A	43	54	44	47
FTPLK1805DW	49	54	49	51
FTPLKBDCA02	46	50	43	46

Note: See Section 4.1.4 for discussion of TSI calculation.

5.2.2.1.7 Phytoplankton Community

Phytoplankton grab samples were collected from Fort Peck Reservoir at three sites (i.e., FTPLK1772A, FTPLK1805DW, and FTPLKBDCA02) during the spring and summer of the 5-year period 2004 through 2008 (Plates 21-23). The following seven taxonomic divisions were represented by taxa collected in the phytoplankton samples: Bacillariophyta (Diatoms), Chlorophyta (Green Algae), Chrysophyta (Golden Algae), Cryptophyta (Cryptomonad Algae), Cyanobacteria (Blue-Green Algae), Pyrrophyta (Dinoflagellate Algae), and Euglenophyta (Euglenoid Algae). The general prevalence of these taxonomic divisions in the reservoir, based on taxa occurrence, were Bacillariophyta > Chlorophyta/Cryptophyta/Cyanobacteria/Pyrrophyta/ > Chrysophyta > Euglenophyta. The diatoms were generally the most abundant algae throughout the entire sampling period based on percent composition (Plates 21-23). The Shannon-Weaver genera diversity indices calculated for the phytoplankton samples collected at the three sites ranged from 0.40 to 2.28 and averaged 1.45 at site FTPLK1772A, 1.64 at site

FTPLK1805DW, and 1.43 at site FTPLKBDCA02. Dominant phytoplankton genera sampled at the three sites in 2008 (i.e., genera comprising more than 10% of the total biovolume of at least one sample collected in 2008) included the Bacillariophyta *Asterionella*, *Aulacoseria, Fragilaria, and Stephanodiscus*; Chlorophyta *Spirogyra*; Cryptophyta *Rhodomonas*; Cyanobacteria *Anabaena*; and Pyrrophyta *Ceratium*. No concentrations of microcystin above 1 ug/l were monitored in Fort Peck Reservoir during 2005 through 2008 (Plates 1 - 6).

5.2.2.1.8 Impairment of Designated Water Quality Beneficial Uses

Based on the State of Montana's impairment assessment methodology (Section 4.1.6.1), the water quality conditions monitored in Fort Peck Reservoir during the 5-year period 2004 through 2008 did not indicate any impairment of designated water quality beneficial uses.

5.2.2.2 Water Quality Trends (1980 through 2008)

Water quality trends over the 29-year period of 1980 to 2008 were determined for Fort Peck Reservoir for Secchi depth, total phosphorus, chlorophyll *a*, and TSI (i.e., trophic status). The assessment was based on near-surface sampling of water quality conditions in the reservoir during the months of May through October at the near-dam, ambient monitoring site (i.e., site FTPLK1772A). Plate 24 displays a scatter-plot of the collected data for the four parameters, a linear regression trend line, and the significance of the trend line (i.e., $\alpha = 0.05$). For the assessment period, Fort Peck Reservoir exhibited significant trends for Secchi depth (decreasing), chlorophyll *a* (increasing), and TSI (increasing) (Plate 24). No significant trend was detected for total phosphorus (Plate 24). Over the 29-year period, the reservoir has generally remained in a mesotrophic state (Plate 24).

5.2.3 EXISTING WATER QUALITY CONDITIONS OF THE MISSOURI RIVER INFLOW TO FORT PECK RESERVOIR

5.2.3.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

The water quality conditions that were monitored in the Missouri River near Landusky, MT (i.e., site FTPNFMORR1) monthly from May through September during the 5-year period 2004 through 2008 are summarized in Plate 25. A review of these results indicated no major water quality concerns. It is noted that the human health standard for arsenic was exceeded for both of the samples collected. The human health standard for arsenic is derived from the maximum contaminant level from Montana's drinking water regulations and uses a bioconcentration factor of 44. It is also noted that monitored levels or iron and manganese significantly exceeded the secondary maximum contaminant level for aesthetics. The high levels of iron and manganese are believed to be a natural condition associated with the geology and soils of the region.

5.2.3.2 Missouri River Inflow Nutrient Flux Conditions

Nutrient flux rates for the Missouri River inflow to Fort Peck Reservoir over the 5-year period 2004 through 2008 were calculated based on water quality samples collected near Landusky, MT (i.e. site FTPNFMORR1) and the instantaneous flow conditions at the time of sample collection (Table 5.4). The maximum nutrient flux rates are attributed to greater nonpoint-source nutrient loadings associated with runoff conditions.

Table 5.4. Summary of nutrient flux rates (kg/sec) calculated for the Missouri River near Landusky, MT (i.e., site FTPNFMORR1) during May through September over the 5-year period 2004 through 2008.

Statistic	Flow (cfs)	Total Ammonia N (kg/sec)	Total Kjeldahl N (kg/sec)	Total NO_3-NO_2 N (kg/sec)	Total Phosphorus (kg/sec)	Dissolved Phosphorus (kg/sec)	Total Organic Carbon (kg/sec)
No. of Obs.	23	23	23	23	23	22	22
Mean	7,586	0.0219	0.2536	0.0117	0.1124	0.0042	0.6282
Median	7,210	0.0135	0.1324	0.0040	0.0186	0.0034	0.5481
Minimum	3,978	n.d.	0.0348	n.d.	0.0034	n.d.	0.1675
Maximum	17,500	0.1033	1.3692	0.0467	1.0550	0.0161	1.4370

Note: Nondetectable values set to 0 for flux calculations.

5.2.3.3 Continuous Water Temperature Monitoring of the Missouri River at USGS Gage Site 06115200 near Landusky, Montana

Through an agreement with the U.S. Geological Survey (USGS), a water temperature monitoring probe was added to the USGS's gage (06115200) on the Missouri River near Landusky, Montana (i.e., site FTPNFMORR1). Beginning in October 2004, hourly water temperature measurements were recorded at the site. Plates 26 through 29 respectively, plot mean daily water temperature and river discharge for the years 2005, 2006, 2007, and 2008. No water temperature data were collected in 2007 (the temperature monitoring probe became inoperable, and USGS was unable to repair it during 2007).

5.2.4 WATER QUALITY AT THE FORT PECK POWERPLANT

5.2.4.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

Plate 30 summarizes the water quality conditions that were monitored from water discharged through Fort Peck Dam during the 5-year period of 2004 through 2008. A review of these results indicated only one possible water quality concern regarding dissolved oxygen. The 1-day dissolved oxygen minimum criterion of 8.0 mg/l for the protection of coldwater B-2 early life stages was not met for 17% of the dissolved oxygen measurements. The 8.0 mg/l criterion is a water column concentration recommended to achieve an in-gravel dissolved oxygen concentrations of 5.0 mg/l. For species that have early life stages exposed directly to the water column, the criterion is 5.0 mg/l. No dissolved oxygen measurements were below 5.0 mg/l. The B-2 classification of the Missouri River downstream of Fort Peck Dam only extends to the confluence of the Milk River, a distance of approximately 10 miles. Given the coldwater species and recruitment present, the 5.0 mg/l water column dissolved criterion may be appropriate for this reach. Also, the dissolved oxygen measurements below 8.0 mg/l tended to occur in later summer when the effects on early life stages are likely to be reduced. Therefore, the observed dissolved oxygen measurements below 8.0 mg/l are not believed to be a significant water quality concern at this time.

5.2.4.2 Impairment of Designated Water Quality Beneficial Uses

Based on the State of Montana's impairment assessment methodology (Section 4.1.6.1), the water quality conditions monitored at the Fort Peck powerplant during the 5-year period 2004 through 2008 did not indicate any impairment of designated water quality beneficial uses.

5.2.4.3 Temperature, Dissolved Oxygen, and Dam Discharge Time-Series Plots

Semiannual time-series plots for temperature, dissolved oxygen, and dam discharge monitored at the Fort Peck powerplant during the 5-year period of 2004 through 2008 were constructed. Water temperatures showed seasonal warming and cooling through each calendar year (Plates 31 - 40). Dissolved oxygen levels remained relatively high and stable during the winter, steadily declined through the spring and summer, and steadily increased during the fall (Plates 41 - 50). The lowest dissolved oxygen levels occurred during the late summer/early fall period. The higher winter, declining spring, and increasing fall dissolved oxygen concentrations are attributed to decreasing dissolved oxygen solubility with warmer water temperatures. The decreasing dissolved oxygen in the July to September period is attributed to ongoing degradation of dissolved oxygen in the lower hypolimnion of Fort Peck Reservoir as the summer progressed. Water is withdrawn from the reservoir into the dam's power tunnels approximately 65 feet above the reservoir bottom. There appeared to be little correlation between discharge rates and measured water temperature and dissolved oxygen concentrations (Plates 31 - 50).

5.2.4.4 Comparison of Monitored Inflow and Outflow Temperatures of the Missouri River at Fort Peck Reservoir

Plates 51, 52, and 53, respectively, plot the mean daily water temperatures monitored at the Missouri River near Landusky, MT (site FTPNFMORR1) and the Fort Peck Dam powerplant (site FTPPP1) for 2005, 2006, and 2008. Inflow temperatures of the Missouri River to Fort Peck Reservoir are generally warmer than the outflow temperatures of Fort Peck Dam during the period of March through August (Plates 51 - 53). Outflow temperatures of the Fort Peck Dam discharge are generally warmer than the inflow temperatures of the Missouri River during the period of September through February (Plates 51 - 53). A maximum temperature difference occurs in the summer when the Missouri River inflow temperature is about 10°C warmer than the Fort Peck Dam outflow temperature. A plot for 2007 comparing water temperatures of the Missouri River inflow and outflow to Fort Peck Reservoir was not possible because water temperatures were not recorded at the USGS gage near Landusky, MT (06115200) in 2007 due to equipment problems.

5.2.5 WATER QUALITY IN THE MISSOURI RIVER DOWNSTREAM FROM FORT PECK DAM

Water temperatures have been monitored in the Missouri River downstream of Fort Peck Dam over the past several years as part of a multi-agency effort to study the pallid sturgeon population in the Missouri and Yellowstone Rivers. Two sites on the Missouri River that have been monitored by the USGS under this effort are the Fort Peck Dam tailwaters (i.e., approximately 5 miles downstream of Fort Peck Dam) and Frazer Rapids (approximately 25 miles downstream of Fort Peck Dam).

The water temperatures monitored at the Fort Peck Dam powerplant during the period 2004 through 2008 were compared to the Missouri River water temperatures monitored by the USGS at their tailwaters and Frazer Rapids sites. Plates 54 through 58, respectively, plot mean daily water temperatures monitored at the three sites and the mean daily discharge of Fort Peck Dam from May through October during 2004, 2005, 2006, 2007, and 2008. During the 5 years, water temperatures monitored at the Fort Peck Dam powerplant from June through August were generally 1°C to 2°C cooler than the water temperatures monitored in the Missouri River at the Fort Peck Dam tailwaters site, and 3°C to 4°C cooler than the water temperatures monitored in the Missouri River at Frazer Rapids (Plates 54 - 58). During early to mid-September of each year, water temperatures monitored at the three sites were somewhat similar. In early September the water temperatures monitored at the Fort Peck Dam powerplant exhibited warming. This is attributed to the cooling and downward expansion of the epilimnion in Fort Peck Reservoir as "fall turnover" of the reservoir approached. It appears that in early September the downward expanding epilimnion intersected with the upper reaches of "withdrawal zone" of the intake for the power

tunnels. This resulted in warmer epilimnetic warmer being captured in the reservoir and discharged through Fort Peck Dam. During late-September to early October, water temperatures monitored at the Fort Peck powerplant were generally warmer than those monitored in the Missouri River downstream of Fort Peck Dam. This is attributed to the slower heat loss from Fort Peck Reservoir than the Missouri River in early fall. Warmer water from the epilimnion of Fort Peck Reservoir is discharged through Fort Peck Dam that cools as it moves down the Missouri River. It is during this time period that the relationship of warmer water temperatures occurring in the Missouri River at Frazer Rapids and cooler water temperatures occurring at the Fort Peck Dam powerplant reverses (Plates 54 - 58).

5.3 GARRISON

5.3.1 BACKGROUND INFORMATION

5.3.1.1 Project Overview

Garrison Dam is located in central North Dakota on the Missouri River at RM 1389.9, about 75 miles northwest of Bismarck, ND and 11 miles south of the town of Garrison, ND. Construction of the project began in 1946, and closure of Garrison Dam in 1953 resulted in the formation of Garrison Reservoir (Lake Sakakawea), which is the largest Corps reservoir in the United States. When full, the reservoir is 178 miles long, up to 6 miles wide, and has 1,884 miles of shoreline. The reservoir contains almost a third of the total storage capacity of the Mainstem System, nearly 24 million acre-ft (MAF). Table 5.5 summarizes how the surface area, volume, mean depth, and retention time of Garrison Reservoir vary with pool elevations. Although still experiencing lower pool levels due to ongoing drought conditions, the reservoir did recover to a pool elevation of 1824.7 at the end of December 2008. This is 13.8 feet higher than the reservoir was 1-year ago at the end of 2007. At a pool elevation of 1824.7 ft-msl, Garrison Reservoir is 12.8 feet below the top of the Carryover Multiple Use Zone (1837.5 ft-msl). Major inflows to the reservoir are the Missouri, Yellowstone, and Little Missouri Rivers. Water discharged through Garrison Dam for power production is withdrawn from Garrison Reservoir at elevation 1672 ft-msl, approximately 2 feet above the reservoir bottom.

Garrison was authorized for the purposes of flood control, recreation, fish and wildlife, hydroelectric power production, water supply, water quality, navigation, and irrigation. Over the period 1967 through 2008, the five generating units at Garrison Dam have produced an annual average 2.268 MWh of electricity, which has a current revenue value of approximately $37 million. The ongoing drought in the western United States has curtailed releases and power production at the Mainstem System projects, including Garrison. Power production at the Garrison Dam generating units averaged an annual 1.411 MWh over the 5-year period 2004 through 2008 Habitat for two endangered species, pallid sturgeon and interior least tern, and one threatened species, piping plover, occurs within the project area. The reservoir is used as a water supply by some individual cabins and by the towns of Four Bears, Mandaree, Park City, Parshall, Riverdale, Trenton, Twin Buttes, and Williston, ND. Garrison Reservoir is an important recreational resource and a major visitor destination in North Dakota.

5.3.1.2 Water Quality Standards Classifications and Section 303(d) Listings

5.3.1.2.1 Garrison Reservoir

The State of North Dakota has classified Garrison Reservoir as a Class 1 lake. As such, the reservoir is to be protected for a coldwater fishery; swimming, boating, and other water recreation; irrigation; stock watering; wildlife; and municipal or domestic use after appropriate treatment. Pursuant to Section 303(d) of the Federal CWA, North Dakota has placed the Garrison Reservoir on the State’s list of impaired waters citing impairment to the uses of fish and other aquatic biota and fish consumption.

Table 5.5. Surface area, volume, mean depth, and retention time of Garrison Reservoir at different pool elevations based on 1988 survey.

Elevation (Feet-msl)	Surface Area (Acres)	Volume (Acre-Feet)	Mean Depth (Feet)*	Retention Time (Years)**
1855	384,480	24,203,180	63.0	1.57
1850	364,265	22,331,620	61.3	1.45
1845	344,460	20,558,360	59.7	1.33
1840	320,600	18,893,560	58.9	1.22
1835	296,210	17,355,220	58.6	1.13
1830	280,520	15,916,490	56.7	1.03
1825	263,525	14,556,980	55.2	0.94
1820	249,665	13,275,410	53.2	0.86
1815	235,600	12,061,430	51.2	0.78
1810	219,955	10,921,980	49.7	0.71
1805	204,453	9,861,138	48.2	0.64
1800	188,998	8,877,219	47.0	0.58
1795	173,070	7,973,682	46.1	0.52
1790	161,295	7,139,184	44.3	0.46
1785	148,759	6,364,791	42.8	0.41
1780	138,809	5,646,736	40.7	0.37
1775	128,261	4,979,890	38.8	0.32

Average Annual Inflow (1967 through 2008) = 16.25 Million Acre-Feet
Average Annual Outflow: (1967 through 2007) = 15.43 Million Acre-Feet
* Mean Depth = Volume ÷ Surface Area.
** Retention Time = Volume ÷ Average Annual Outflow.
Note: Exclusive Flood Control Zone (elev. 1854-1850 ft-msl), Annual Flood Control and Multiple Use Zone (elev. 1850-1837.5 ft-msl), Carryover Multiple Use Zone (elev. 1837.5-1775 ft-msl), and Permanent Pool Zone (elev. 1775-1670 ft-msl). All elevations are in the NGVD 29 datum.

The impairment of fish and other aquatic biota is attributed to the stressors of low dissolved oxygen and warm water temperatures, and the impairment to fish consumption is attributed to methyl-mercury contamination if fish tissue. The State of North Dakota has issued a fish consumption advisory for Garrison Reservoir due to mercury concerns.

5.3.1.2.2 Missouri River Downstream of Garrison Dam

The State of North Dakota has classified the entire Missouri River as a Class 1 stream. As such, the river is to be suitable for the propagation and/or protection of resident fish species and other aquatic biota; swimming, boating, and other water recreation; irrigation; stock watering; wildlife; and municipal or domestic use after appropriate treatment. The river has not been placed on the State's Section 303(d) list of impaired waters. The State of North Dakota has issued a fish consumption advisory for the Missouri River due to mercury concerns.

5.3.1.3 Management of Coldwater Habitat in Garrison Reservoir

5.3.1.3.1 Coldwater Habitat Criteria – Water Temperature and Dissolved Oxygen

North Dakota defines Class 1 lakes, including Garrison Reservoir, as waters capable of supporting growth of coldwater fish species (e.g., salmonids) and associated biota. Water temperature and dissolved oxygen levels are primary water quality factors that determine the suitability of water for coldwater aquatic life. The State of North Dakota recently promulgated a hypolimnetic temperature

criterion of 15°C for Class 1 lakes and reservoirs that are thermally stratified. The State also adopted a water quality standard that states that Lake Sakakawea must maintain a minimum volume of water of 500,000 acre-feet that has a temperature of 15°C or less and a dissolved oxygen concentration of not less than 5 mg/l.

5.3.1.3.2 Implementation of Short-term Water Quality Management Measures to Preserve Coldwater Habitat in Garrison Reservoir

The most crucial period for the support of coldwater habitat in Garrison Reservoir is when it begins to cool in late summer. As the thermocline moves deeper, the volume of the coldwater hypolimnion continues to decrease while the expanding epilimnion has not cooled enough to be supportive of coldwater habitat. At the same time, hypolimnetic dissolved oxygen concentrations are approaching their maximum degradation and low dissolved oxygen levels are moving upward from the reservoir bottom and "pinching off" coldwater habitat from below. This situation continues to worsen until the epilimnion cools enough to be supportive of coldwater habitat and the reservoir eventually experiences fall turnover. The volume of the hypolimnion (i.e., coldwater habitat) occurring in Garrison Reservoir during the summer decreases with lower pool levels.

As drought conditions persisted in early 2005, water levels in Garrison Reservoir had fallen to a record low pool elevation of 1805.8 feet-msl on May 12, 2005. At that time it was felt that unless emergency water quality management measures were implemented in 2005 to preserve the coldwater habitat in the reservoir, the recreational sport fishery would likely be adversely impacted. The reduction of coldwater habitat is exacerbated by withdrawals through the Garrison Dam intake structure. Because the invert elevation of the intake portals to the Garrison Dam power tunnels (i.e., penstocks) is 2 feet above the reservoir bottom, water drawn through the penstocks comes largely from the lower depths of the reservoir. Thus, during the summer thermal-stratification period, water is largely drawn from the hypolimnetic volume of Garrison Reservoir. Three short-term water quality management measures were identified for implementation in 2005 in an effort to preserve the coldwater habitat in the reservoir. These measures, which were implemented at Garrison Dam, included: 1) application of a plywood barrier to the dam's intake trash racks, 2) utilization of head gates to restrict the opening to the dam's power tunnels, and 3) modification of the daily flow cycle and minimum flow releases from the dam. The three implemented water quality management measures were targeted at drawing water into the dam from higher elevations within Garrison Reservoir.

5.3.1.3.2.1 Application of a Plywood Barrier to the Dam's Intake Trash Racks

The five power tunnels at Garrison Dam are screened at the upstream end of the water passage by trash racks. These trash racks prevent large objects from entering the penstocks and causing serious damage to the wicket gates and turbine. Each of the five Units has two intake passages for a total of ten intakes. The trash rack for each of the ten intakes consists of seven separate frame sections. The trash rack fits into the trash rack slots at the front of the intake passage piers. A hook for each rack is fixed to the top of the frame. A lifting beam and mobile crane is used to raise and lower each trash rack.

The existing trash racks were modified to raise the elevation where water was withdrawn from Garrison Reservoir. The trash rack modification consisted of installing plywood sheathing on the upstream side of the existing trash rack grates on the passages to Units 2 and 3. The plywood sheathing covered the lower 48 feet of the trash racks (i.e., approximately elevation 1672 to 1720 ft-msl) with the exception of a 3-inch slot at the very bottom for passing sediments. The plywood installation was completed on the trash racks to Unit 3 on July 15, 2005 and on the trash racks to Unit 2 on July 20, 2005. The plywood was inspected with an underwater camera in the spring of 2006 and determined to still be in good condition.

In mid-May 2007, attempts were made to install plywood barriers to the trash racks of Unit 1. Due to a large tree at the bottom of the east intake to Unit 1, plywood could not be installed on all the trash racks. The bottom trash rack on the east side of Unit 1 could not be removed and did not receive a plywood barrier. There are 2½ trash racks with plywood barriers on the east side of Unit 1 and 3½ trash racks with plywood on the west side. Therefore, a plywood barrier existed on the west side of Unit 1 from elevation 1672 to 1720 ft-msl, and on the east side of Unit 1 from elevation 1688 to 1720 ft-msl. The plywood for the trash racks for Unit 1 was installed and the Unit returned to service on May 19, 2007. The plywood barriers were still in place on the trash racks of Units 1, 2, and 3 as of December 31, 2008.

5.3.1.3.2.2 Utilization of Head Gates to Restrict the Opening to the Dam's Power Tunnels

Each of the intake passages to all five power tunnels have operational head gates that control flow into the penstocks. It was reasoned that lowering one of the two head gates to block a single passage to the power tunnel should increase the velocity of water drawn into the power tunnel, given the total flow through the power tunnel remained the same. Increasing the velocity of the water drawn into the intake could pull water from a higher elevation in Garrison Reservoir and possibly help maintain the reservoir's deeper, colder volume. To implement this measure in 2006, single head gates on the passages to Units 1 and 4 were lowered on July 5, 2006. Similarly in 2007, single head gates on the passages to Units 1 and 4 were lowered on May 30, 2007 and were raised on October 2, 2007. The head gates were not lowered in 2008.

5.3.1.3.2.3 Modification of Daily Flow Cycle and Maximum and Minimum Flow Releases

Past water quality monitoring at the Garrison Dam powerhouse indicated that the vertical extent of the withdrawal zone in Garrison Reservoir during summer thermal stratification was dependent on the discharge rate of the dam. Warmer water high in dissolved oxygen was drawn down from higher elevations in the reservoir under higher discharge rates, and colder water low in dissolved oxygen was drawn from the lower depths of the reservoir under lower discharge rates. The influence of the dam's discharge rate on the reservoir withdrawal zone is believed to be partly attributed to the design of the intake structure and submerged intake channel.

To the extent possible, flow releases from Garrison Dam during 2005 through 2008 were modified to try to maximize the water drawn from higher elevations and minimize the water drawn from lower elevations in Garrison Reservoir. The following two flow release modifications were pursued: 1) daily flow releases should be in either a maximum or minimum mode; and 2) minimum flows should be discharged through Units 2 and 3, which have the "full" plywood barriers in place. Unit 1, with a "partial" plywood barrier, was used as a back-up to Units 2 and 3 for discharging minimum flows.

5.3.1.3.3 Performance Assessment Report

A more detailed discussion of the implementation of the short-term water quality management measures and their effects through 2005 is given in the Performance Assessment Report, "Garrison Cold Water Fishery Performance Assessment" (USACE, 2006b).

5.3.1.4 <u>Ambient Water Quality Monitoring</u>

The District has monitored water quality conditions at the Garrison Project since the late 1970's. Water quality monitoring locations have included sites on the reservoir and on the inflow to and outflow from the reservoir. A 3-year intensive water quality survey was completed at the Garrison Project in 2005 and the findings of the intensive survey are available in the separate report, "Water Quality Conditions

Monitored at the Corps' Garrison Project in North Dakota during the 3-Year period 2003 through 2005" (USACE, 2006c). Figure 5.3 shows the location of sites at the Garrison Project that have been monitored by the District for water quality during the 5-year period 2004 through 2008. The near-dam location (i.e., site GARLK1390A) has been continuously monitored since 1980.

5.3.2 WATER QUALITY IN GARRISON RESERVOIR

5.3.2.1 Existing Water Quality Conditions (2004 through 2008)

5.3.2.1.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

Water quality conditions that were monitored in Garrison Reservoir at sites GARLK1390A, GARLK1399DW, GARLK1412DW, GARLK1428DW, GARLK1445DW, GARLK1454DW, and GARLK1481DW from May through September during the 5-year period 2004 through 2008 are summarized in Plates 59 through 65. A review of these results indicated possible water quality concerns regarding water temperature and dissolved oxygen for the support of coldwater fishery habitat in the hypolimnion of Garrison Reservoir. For assessment purposes, the top of the hypolimnion was defined as the depth where a temperature drop of at least 0.5°C last occurs over a 1-meter depth increment. Monitored water quality conditions in the hypolimnion of Garrison Reservoir regularly exceeded the 15°C and 5 mg/l criteria for temperature and dissolved oxygen (Plates 59 - 65). Dissolved oxygen levels in the hypolimnion continually degrade along the reservoir bottom as summer progresses and fall below 5 mg/l in late summer. Low dissolved oxygen conditions occur in the upstream reaches of the hypolimnion first and progress towards the dam. As the summer progresses, low dissolved oxygen conditions move up from the reservoir bottom into the mid and upper reaches of the hypolimnion. This pinching off of coldwater habitat threatens the support of the coldwater fishery in the reservoir, especially under low pool levels during drought conditions. The assessment of coldwater fishery habitat in Garrison Reservoir is further discussed in Section 5.3.2.1.4. The lowest dissolved oxygen concentration measured at the seven monitored sites was 1.0 mg/l and occurred at site GARLK1445DW on August 29, 2006.

5.3.2.1.2 Summer Thermal Stratification

5.3.2.1.2.1 2008 Monthly Longitudinal Temperature Contour Plots

Late-spring and summer thermal stratification of Garrison Reservoir during 2008 is described by longitudinal temperature contour plots along the length of the reservoir (Plates 66 - 70). The contour plots are based on depth-profile temperature measurements taken monthly from May through September along the submerged Missouri River channel. As seen in Plates 66 through 70, water temperature in Garrison Reservoir varies longitudinally from the dam to the reservoir's upstream reaches and vertically from the reservoir surface to the bottom. The near-surface water in the upstream reaches of the reservoir warms up sooner in the spring than the near-surface water near the dam (Plates 66 and 67). By mid-summer a strong thermocline becomes established in the downstream reaches of the reservoir, and the near-surface waters of the entire reservoir above the thermocline are a fairly uniform temperature (Plates 68 and 69). As the near-surface waters of the reservoir cool in the late summer, the thermocline is pushed deeper and the wind-mixed upper waters are fairly uniform in temperature (Plate 70). The vertical variation in temperature is most prevalent in the deeper area of the reservoir towards the dam where a strong thermocline becomes established during the summer. The shallower upstream reaches of Garrison Reservoir do not exhibit much vertical variation of temperature during mid to late summer as wind action allows for the water column to completely mix.

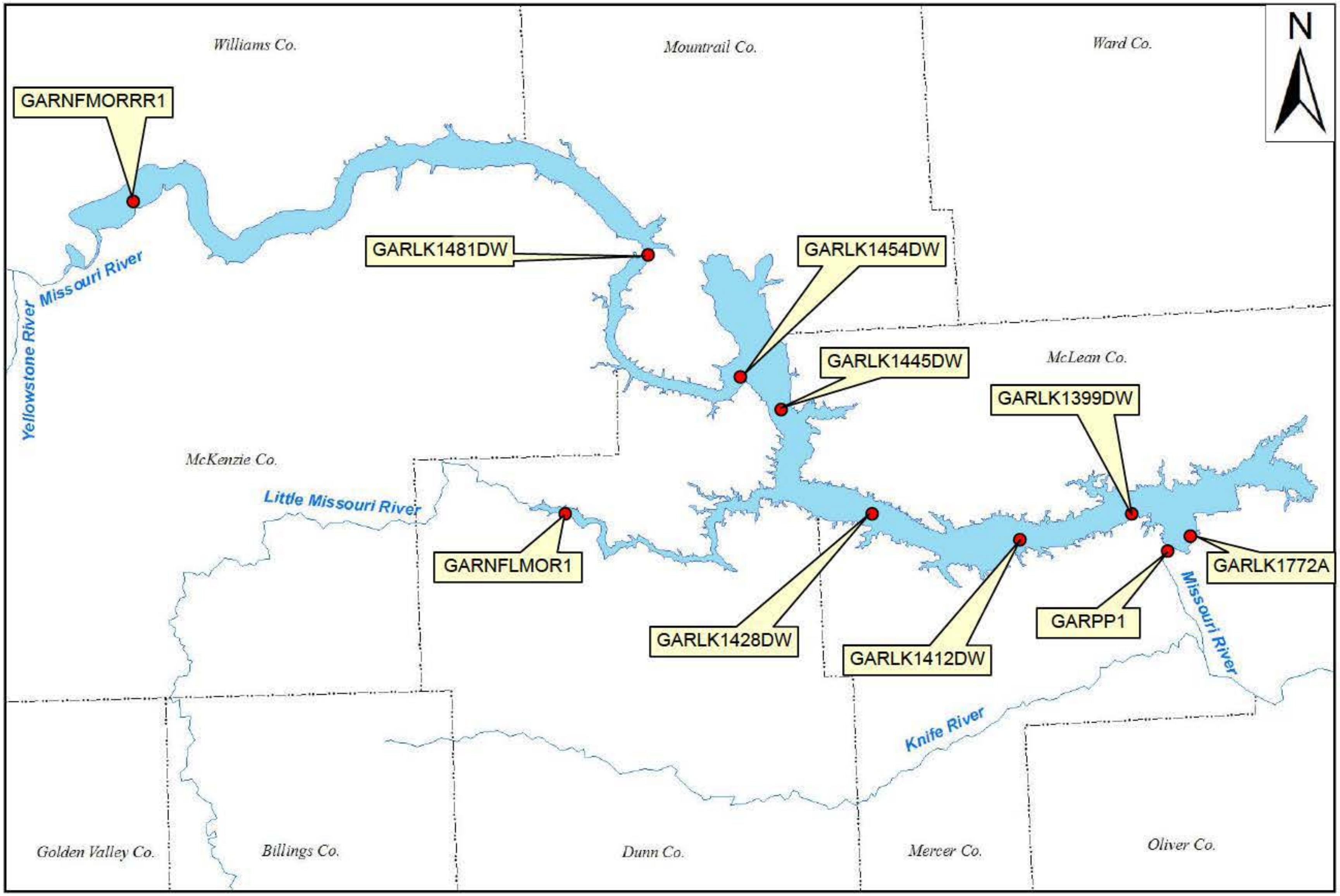

Figure 5.3. Location of sites where water quality monitoring was conducted by the District at the Garrison Project during the 5-year period 2004 through 2008.

5.3.2.1.2.2 Near-Dam Temperature Depth-Profile Plots

Existing summer thermal stratification of Garrison Reservoir at the deep water area near the dam is described by the depth-profile temperature plots measured over the past 5 years. Depth-profile temperature plots measured during the summer were compiled (Plate 71). The plotted depth-profile measurements indicate that a significant temperature-depth gradient occurs in Garrison Reservoir in the near-dam lacustrine area during the summer, and a thermocline becomes established at a depth of about 25 meters (Plate 71).

5.3.2.1.3 Summer Dissolved Oxygen Conditions

5.3.2.1.3.1 2008 Monthly Longitudinal Dissolved Oxygen Contour Plots

Dissolved oxygen contour plots were constructed along the length of Garrison Reservoir based on depth-profile measurements taken in May, June, July, August, and September of 2008 (Plates 72 - 76). During the summer of 2008, dissolved oxygen conditions in Garrison Reservoir varied longitudinally from the dam to the reservoir's upstream reaches and vertically from the reservoir surface to the bottom (Plates 72 - 76). Dissolved oxygen levels below 5 mg/l first appeared near the reservoir bottom in the middle reaches of the reservoir in early-August (Plate 75). As the summer progressed, dissolved oxygen concentrations below 5 mg/l moved along the reservoir bottom to the area near the dam (Plates 75 and 76). The earlier occurrence of low dissolved oxygen concentrations in the near-bottom water of the middle reaches of Garrison Reservoir is attributed to the increased allochthonous organic loading in the transition zone of the reservoir and the lesser hypolimnetic volume available for assimilation of the oxygen demand. As this material decomposes, a "pool" of water with low dissolved oxygen levels accumulates near the bottom in this area of the reservoir. Decomposition of autochthonous organic matter also occurs in the lacustrine zone and results in dissolved oxygen degradation as the summer progresses, although at a slower rate than what occurs in the transition zone. The recovery of near-bottom dissolved oxygen concentrations to saturation levels takes longer in the lacustrine zone nearer the dam because of the longer time needed for thermal stratification to breakdown and mixing within the water column to occur in the deeper water. The near-bottom location of the power tunnel intakes at the dam could also seemingly result in an interflow along the reservoir bottom that could promote the movement of oxygen-demanding material and low dissolved oxygen water from the middle reaches of the reservoir to the dam. Any interflow affect would likely increase as pool elevations drop and the reservoir's retention time decreases.

5.3.2.1.3.2 Near-Dam Dissolved Oxygen Depth-Profile Plots

Existing summer dissolved oxygen conditions in Garrison Reservoir at the deep water area near the dam are described by the depth-profile dissolved oxygen plots measured over the past 5 years. Depth-profile dissolved oxygen plots measured during the summer were compiled (Plate 77). Dissolved oxygen levels exhibited a significant gradient with depth and tended toward a clinograde vertical distribution (Plate 77). During the period of 2004 through 2008, dissolved oxygen concentrations in the lower hypolimnion fell below 5 mg/l as the summer progressed, with the lowest levels occurring in late-August and September. The lowest dissolved oxygen concentration measured at this site over the past 5 years was 3.8 mg/l.

5.3.2.1.4 Occurrence of Coldwater Fishery Habitat in Garrison Reservoir

The occurrence of coldwater habitat (i.e., water temperature ≤ 15°C and dissolved oxygen ≥ 5 mg/l) in Garrison Reservoir was estimated from collected water temperature and dissolved oxygen depth-

profile measurements and defined reservoir elevation and volume relationships. Plate 78 displays a plot of pool elevations and the coldwater fishery habitat estimated to have been present in Garrison Reservoir during the summers of 2003 through 2008. As previously mentioned, the State of North Dakota recently promulgated a water quality standard that states that Lake Sakakawea must maintain a minimum volume of water of 500,000 acre-feet that has a temperature of 15°C or less and a dissolved oxygen concentration of not less than 5 mg/l. Plate 79 displays the same information shown in Plate 78 except the y-axis is scaled to a maximum value of 2-million acre-feet. This allows the estimated coldwater habitat volumes near the 500,000 acre-feet water quality standard to be better discerned. The 500,000 ac-ft water quality standard was seemingly not met in Garrison Reservoir in late-summer (i.e., September) during the 6-year period 2003 through 2008. There is seemingly a critical period for the occurrence of coldwater habitat in Garrison Reservoir during and just prior to fall turnover of the reservoir.

The occurrence of coldwater habitat in Garrison Reservoir is believed to be highly dependent on pool elevation. Since coldwater habitat only occurs in the hypolimnion of the reservoir during the summer, the size of the hypolimnion will directly determine the amount of coldwater habitat potentially available. The upper extent of the hypolimnion is delineated by the thermocline (i.e., zone of rapid temperature decline) which separates the colder hypolimnion from the warmer, less dense water of the epilimnion. Depending on climatic factors, the thermocline in an individual reservoir will generally be established at a similar depth from year to year. Therefore, a greater hypolimnetic volume will tend to occur under higher pool elevations and a lesser hypolimnetic volume will tend to occur under lower pool elevations. The pool elevation in late-spring and early summer when the thermocline first becomes established is especially important as later changes in pool elevations are mitigated somewhat by the stratification already established. A larger hypolimnetic volume also has a greater assimilative capacity for oxygen demanding materials which can degrade dissolved oxygen levels in the hypolimnion below the coldwater habitat standard of 5 mg/l.

The relationship between the occurrence of coldwater habitat and pool elevation is generally seen in the coldwater habitat estimated to have occurred in Garrison Reservoir during 2003 through 2008 (Plates 78 and 79). The year with the higher pool elevations (i.e., 2003) generally had the highest estimated occurrence of coldwater habitat. The years with the lower pool elevations (i.e., 2005, 2006, and 2007) generally had the lowest estimated occurrence of coldwater habitat. It is noted that 2004 was an atypical year of cloudy, cooler weather that resulted in cooler lake temperatures. Atypical pool elevations occurred in 2008. In 2008, pool elevations rose from the lowest level to near the highest levels recorded during the 6-year period 2003 through 2008 (Plate 78). The seemingly lower occurrence of coldwater habitat estimated in 2008 may be a result of the lower pool levels that occurred in late-spring when the hypolimnion was becoming established (Plate 78).

5.3.2.1.5 Water Clarity

5.3.2.1.5.1 Secchi Transparency

Figure 5.4 displays a box plot of the Secchi depth transparencies measured along Garrison Reservoir at the four sites GARLK1481DW, GARLK1445DW, GARLK1412DW, and GARLK1390A during the 5-year period 2004 through 2008. Secchi depth transparency significantly increased in a downstream direction between sites GARLK1481DW, GARLK1445DW, and GARLK1412DW (Figure 5.4). This is attributed to suspended sediment in the inflowing Missouri River settling out in the reservoir as current velocities slow. The surface waters near Garrison Dam are significantly clearer than the upstream regions of the reservoir. Under the conditions that were monitored during the 2004 to 2008 period, it appears that site GARLK1481DW was in the riverine zone; site GARLK1445DW was in the transition zone; and sites GARLK1412DW and GARLK1390A were in the lacustrine zone of the reservoir.

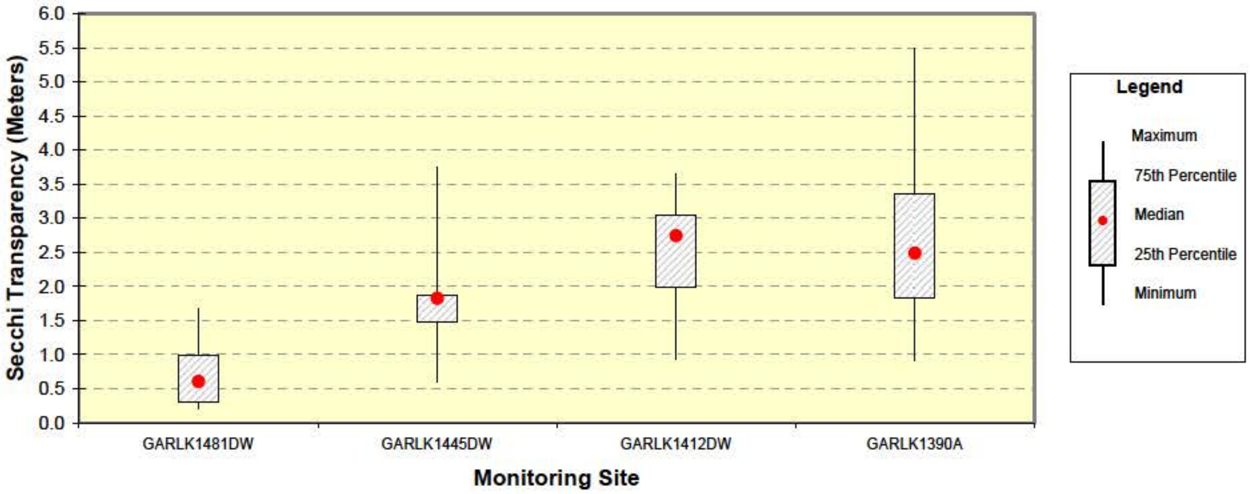

Figure 5.4. Box plot of Secchi transparencies measured in Garrison Reservoir during the 5-year period 2004 through 2008.

5.3.2.1.5.2 Turbidity

Monthly (June, July, August, and September) longitudinal contour plots were prepared from the depth-profile turbidity measurements taken at sites GARLK1390A, GARLK1412DW, GARLK1445DW, GARLK1481DW, and GARNFMORRR1 during 2008 (Plates 80 - 83). As seen in Plates 81 through 84, turbidity levels in Garrison Reservoir vary longitudinally from the dam to reservoir's upstream reaches and vertically from the reservoir surface to the bottom. Turbidity levels are significantly higher in the upstream reaches of the reservoir as compared to the area near the dam. This is attributed to the turbid conditions of the inflowing Missouri River. It also appears that turbidity plumes may move through Garrison Reservoir as interflows; especially along the bottom. This may be attributed to colder inflowing snowmelt runoff, with higher turbidity levels, flowing underneath warmer surface waters in Garrison Reservoir as an interflow along the bottom. Given the low chlorophyll *a* concentrations monitored in Garrison Reservoir (Plates 59 - 65), turbidity in the reservoir appears to be largely due to suspended inorganic material.

5.3.2.1.6 Comparison of Near-Surface and Near-Bottom Water Quality Conditions

Paired near-surface and near-bottom water quality samples collected from Garrison Reservoir during the summer were compared. Near-surface conditions were represented by samples collected within 2-meters of the reservoir surface, and near-bottom conditions were represented by samples collected within 2-meters of the reservoir bottom. The compared samples were collected at the near-dam site GARLK1390A during the 5-year period 2004 through 2008. During the period a total of 19 paired samples were collected monthly from June through September. Box plots were constructed to display the distribution of the paired near-surface and near-bottom measurements for the following parameters: water temperature, dissolved oxygen, oxidation-reduction potential (ORP), pH, alkalinity, total organic carbon (TOC), total Kjeldahl nitrogen (TKN), total ammonia, and total phosphorus (Plate 84). A paired two-tailed t-test was used to determine if the sampled near-surface and near-bottom conditions for the paired samples were significantly different ($\alpha = 0.05$). The sampled near-surface and near-bottom conditions were significantly different for all the assessed parameters except total ammonia and total phosphorus. Parameters that were significantly lower in the near-bottom water of Garrison Reservoir included: water temperature ($p < 0.001$), dissolved oxygen ($p < 0.001$), pH ($p < 0.001$), TOC ($p < 0.05$), and TKN (<0.05). Parameters that were significantly higher in the near-bottom water included: ORP ($p < 0.001$) and alkalinity ($p < 0.05$).

5.3.2.1.7 Reservoir Trophic Status

Trophic State Index (TSI) values for Garrison Reservoir were calculated from monitoring data collected during the 5-year period 2004 through 2008 (Table 5.6). The calculated TSI values indicate that the lacustrine zone of the reservoir (i.e., sites GARLK1390A and GARLK1412DW) is mesotrophic, the transition zone (i.e., site GARLK1445DW) is moderately eutrophic, and the riverine zone (i.e., site GARLK1481DW) is eutrophic. However, it is noted that the calculated average TSI value for the riverine zone is greatly influenced by the low water clarity in this part of the reservoir. This lack of water clarity is largely attributed to suspended inorganic material delivered to the reservoir by the Missouri River. Thus, the higher TSI values in the riverine zone seemingly are not indicative of increased algal growth associated with nutrient enrichment. It is noted that the total phosphorus nutrient guideline defined by North Dakota for lake improvement or management (i.e., 0.02 mg/l) was regularly exceeded throughout Garrison Reservoir (Tables 59 - 65).

Table 5.6. Mean Trophic State Index (TSI) values calculated for Garrison Reservoir. TSI values are based on monitoring at the identified four sites during the 5-year period 2004 through 2008.

Monitoring Site	Mean – TSI (Secchi Depth)	Mean – TSI (Total Phos.)	Mean – TSI (Chlorophyll)	Mean – TSI (Average)
GARLK1390A	47	54	45	49
GARLK1412DW	47	52	47	49
GARLK1445DW	53	51	51	52
GARLK1481DW	68	56	57	61

Note: See Section 4.1.4 for discussion of TSI calculation.

5.3.2.1.8 Phytoplankton Community

Phytoplankton grab samples were collected from Garrison Reservoir at four sites (i.e., GARLK1390A, GARLK1412DW, GARLK1445DW, and GARLK1481DW) during the spring and summer of the 5-year period 2004 through 2008 (Plates 85 - 88). The following seven taxonomic divisions were represented by taxa collected in the phytoplankton samples: Bacillariophyta (Diatoms), Chlorophyta (Green Algae), Chrysophyta (Golden Algae), Cryptophyta (Cryptomonad Algae), Cyanobacteria (Blue-Green Algae), Pyrrophyta (Dinoflagellate Algae), and Euglenophyta (Euglenoid Algae). The general prevalence of these taxonomic divisions in the reservoir, based on taxa occurrence, were Bacillariophyta > Chlorophyta > Cryptophyta/Cyanobacteria/Pyrrophyta > Chrysophyta > Euglenophyta. The diatoms were generally the most abundant algae throughout the entire sampling period based on percent composition (Plates 85 - 88). The Shannon-Weaver genera diversity indices calculated for the phytoplankton samples collected at the four sites ranged from 0.34 to 2.69 and averaged 1.36 at site GARLK1390A, 1.44 at site GARLK1412DW, 1.50 at site GARLK1445DW, and 1.68 at site GARLK1481DW. Dominant phytoplankton genera sampled at the four sites in 2008 (i.e., genera comprising more than 10% of the total biovolume of at least one sample collected in 2008) included the Bacillariophyta *Asterionella*, *Aulacoseria, Cyclotella, Fragilaria, Stephanodiscus, Synedra, and Tablellaria*; Chlorophyta *Chlamydomonas*; Chrysophyta *Dinobryon*; Cryptophyta *Rhodomonas*; and Cyanobacteria *Anabaena*. No concentrations of microcystin above 1 ug/l were monitored in Garrison Reservoir during 2005 through 2008 (Plates 59, 61, 63, and 65).

5.3.2.1.9 Impairment of Designated Water Quality Beneficial Uses

Based on the State of North Dakota's impairment assessment methodology (Section 4.1.6.3), the water quality conditions monitored in Garrison Reservoir during the 5-year period 2004 through 2008 indicates impairment of coldwater fishery habitat. The percent of hypolimnetic dissolved oxygen

measurements below 5 mg/l ranged from 15 to 32 percent of the measurements taken at the seven reservoir monitoring sites (Plates 59 - 65). The estimated "instantaneous" volume of coldwater habitat present in Garrison Reservoir fell below 500,000 ac-ft every year from 2002 through 2008 based on monitored temperature and dissolved oxygen depth-profiles.

5.3.2.2 Water Quality Trends (1980 through 2008)

Water quality trends over the 29-year period of 1980 through 2008 were determined for Garrison Reservoir for Secchi depth, total phosphorus, chlorophyll *a*, and TSI (i.e., trophic status). The assessment was based on near-surface sampling of water quality conditions in the reservoir during the months of May through October at the near-dam, ambient monitoring site (i.e., site GARLK1390A). Plate 89 displays a scatter-plot of the collected data for the four parameters, a linear regression trend line, and the significance of the trend line (i.e., α = 0.05). For the assessment period, Garrison Reservoir did not exhibit significant trends for any of the four parameters (Plate 89). Over the 29-year period, the reservoir has generally remained in a mesotrophic state (Plate 89).

5.3.3 EXISTING WATER QUALITY CONDITIONS OF THE MISSOURI RIVER INFLOW TO GARRISON RESERVOIR

5.3.3.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

The water quality conditions that were monitored in the Missouri River near Williston, ND (i.e., site GARNFMORRR1) monthly from May through September during the 5-year period 2004 through 2008 are summarized in Plate 90. A review of these results indicated no major water quality concerns. It is noted that monitored levels of total aluminum greatly exceeded the acute total aluminum criterion for aquatic life protection; however, the monitored levels of dissolved aluminum were well below the criterion. It is not believed the monitored aluminum levels are indicative of a water quality problem. It is also noted that very high levels of total iron were monitored. The high levels of total aluminum and iron are believed to be a natural condition associated with the geology and soils of the region.

5.3.3.2 Missouri River Inflow Nutrient Flux Conditions

Nutrient flux rates for the Missouri River inflow to Garrison Reservoir over the 5-year period of 2004 through 2008 were calculated based on water quality samples collected near Williston, North Dakota (i.e. site GARNFMORRR1) and the estimated flow conditions at the time of sample collection (Table 5.7). The maximum nutrient flux rates are attributed to greater nonpoint source nutrient loadings associated with runoff conditions.

Table 5.7. Summary of nutrient flux rates (kg/sec) calculated for the Missouri River near Williston, ND (i.e., site GARNFMORRR1) during April through September over the 5-year period 2004 through 2008.

Statistic	Flow (cfs)	Total Ammonia N (kg/sec)	Total Kjeldahl N (kg/sec)	Total NO_3-NO_2 N (kg/sec)	Total Phosphorus (kg/sec)	Dissolved Phosphorus (kg/sec)	Total Organic Carbon (kg/sec)
No. of Obs.	27	27	27	27	27	26	26
Mean	18,350	0.0287	0.7422	0.0563	0.3181	0.0144	1.5032
Median	14,016	0.0117	0.5800	n.d.	0.2000	0.0086	1.1379
Minimum	7,649	n.d.	0.1000	n.d.	0.0400	n.d.	0.4862
Maximum	52,320	0.1300	1.7600	0.2977	1.1000	0.0680	4.5720

Note: Nondetectable values set to 0 for flux calculations.

5.3.3.3 Continuous Water Temperature Monitoring of the Missouri River at USGS Gage Site 06330000 near Williston, North Dakota

Through an agreement with the USGS, a water temperature monitoring probe was added to the USGS's gage (06330000) on the Missouri River near Williston, ND (i.e., site GARNFMORRR1). Beginning in 2005, water temperature measurements were recorded at the site. Plates 91 through 94, respectively, plot mean daily water temperature and river discharge determined for 2005, 2006, 2007, and 2008.

5.3.4 WATER QUALITY AT THE GARRISON POWERPLANT

5.3.4.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

Plate 95 summarizes the water quality conditions that were monitored from water discharged through Garrison Dam during the 5-year period 2004 through 2008. The monitored water quality conditions do not indicate any significant water quality concerns. One dissolved oxygen observation measured on September 20, 2004 did not meet the criterion of 5 mg/l (Plate 95). All dissolved oxygen concentrations measured during the 2005 through 2008 period were above 5 mg/l. The maximum water temperature measured during the 5-year period was 18.2°C. The monitored water temperatures are believed supportive of the coolwater fishery that exists in the Garrison Dam tailwaters.

5.3.4.2 Temperature, Dissolved Oxygen, and Dam Discharge Time-Series Plots

Semiannual time series plots for temperature and dam discharge monitored hourly at the Garrison powerplant during the 6-year period of 2003 through 2008 were constructed (Plates 96 - 106). Monitored water temperatures showed seasonal cooling and warming through each calendar year. Daily water temperatures remained fairly stable during the winter, early spring, and late fall and exhibited considerable variability during the late spring, summer, and early fall. When thermal stratification becomes established in Garrison Reservoir during the late spring, the temperature of the water discharged through the dam becomes highly dependent upon the discharge rate of the dam. This indicates that the vertical extent of the withdrawal zone in the reservoir is dependent upon the discharge rate of the dam. This is believed to be a result of the design of the intake structure (i.e., bottom withdrawal) and the presence of the submerged intake channel leading to the intake structure. Water is likely drawn from an extended vertical zone in Garrison Reservoir year-round, but is only evident in the temperatures monitored at the powerplant during thermal stratification of the reservoir in the summer. A decrease in the daily variation of the monitored temperatures in the summers of 2005 through 2008 occurred after the installation of plywood barriers on the lower portion of the trash racks in front of penstocks 2 and 3 in 2005 and penstock 1 in 2007. Plates 107 and 108 show plots of hourly water temperatures measured at the Garrison powerplant during the period of June through October for 2003 through 2008. It is evident that the installation of the plywood barriers in 2005 reduced the variability and raised the temperature of the water passed through Garrison Dam and discharged to the Missouri River downstream during the summer. The increase in temperature was, on average, about 2°C.

Semiannual time series plots for dissolved oxygen and dam discharge monitored hourly at the Garrison powerplant during the 6-year period of 2003 through 2008 were also constructed (Plates 109 - 119). Dissolved oxygen levels remained relatively high and stable during the winter, steadily declined through the spring and summer, and steadily increased during the fall. The lowest dissolved oxygen levels occurred during the late summer/early fall period. The higher winter, declining spring, and increasing fall dissolved oxygen concentrations are attributed to decreasing dissolved oxygen solubility with warmer water temperatures. The decreasing dissolved oxygen in the July to September period is attributed to ongoing degradation of dissolved oxygen in the lower hypolimnion in Garrison Reservoir as

the summer progressed. Water is withdrawn from Garrison Reservoir into the dam's power tunnels approximately 2 feet above the reservoir bottom. During the late summer, dissolved oxygen levels were highly correlated to dam discharge rates in 2003 and 2004 and not as correlated in 2005, 2006, 2007, and 2008. This is attributed to the implementation of the short-term water quality management measures in 2005 through 2008.

Plates 120 and 121 show a plot of hourly dissolved oxygen concentrations measured at the Garrison powerplant during the period of June through October for 2003, 2004, 2005, 2006, 2007, and 2008. It is evident that the installation of the short-term water quality management measures in 2005 raised the dissolved oxygen concentrations of water passed through Garrison Dam and discharged to the Missouri River downstream during the summer. The plywood barriers allowed epilimnetic water, higher in dissolved oxygen, to be drawn into the power tunnel intakes and then to be discharged from the dam. Although the short-term water quality management measures were implemented to preserve coldwater habitat in Garrison Reservoir, they also had the probable benefit of preventing dissolved oxygen levels below the State of North Dakota's water quality standards criterion (i.e., 5 mg/l) from occurring in the Garrison Dam tailwaters during late summer low flow releases (Plate 121).

5.3.4.3 Comparison of Monitored Inflow and Outflow Temperatures of the Missouri River at Garrison Reservoir

Plates 122 through 125, respectively, plot the mean daily water temperatures monitored at the Missouri River near Williston, ND (site GARNFMORRR1) and the Garrison Dam powerplant (site GARPP1) for 2005, 2006, 2007, and 2008. Inflow temperatures of the Missouri River to Garrison Reservoir are generally warmer than the outflow temperatures of Garrison Dam during the period of April through September (Plates 122 - 125). Outflow temperatures of the Garrison Dam discharge are generally warmer than the inflow temperatures of the Missouri River during the period of October through March (Plates 122 - 125). A maximum temperature difference occurs in the summer when the Missouri River inflow temperature is about 10°C warmer than the Garrison Dam outflow temperature.

5.3.5 WATER QUALITY IN THE MISSOURI RIVER DOWNSTREAM OF GARRISON DAM

5.3.5.1 Water Temperatures Monitored at Garrison Dam and the USGS Gage Station at Bismarck, North Dakota in 2005 and 2006

Through an agreement with the USGS, a water temperature monitoring probe was added to the USGS's gage on the Missouri River at Bismarck, ND in 2005. The USGS gage at Bismarck, ND is located at RM1314.7 and is approximately 75 miles downstream of Garrison Dam. Plates 126 through 129, respectively, plot the mean daily flows and water temperatures monitored at the Garrison powerplant and USGS gage at Bismarck, ND in 2005, 2006, 2007, and 2008. Annually, the mean daily water temperature of the Missouri River at Bismarck is warmer than the Garrison Dam discharge from April through August and generally cooler from September through March (Plates 126 - 129). During the summers of 2005, 2006, 2007, and 2008 mean daily water temperatures at Bismarck were, respectively, up to 11°C, 6°C, 8°C, and 7°C warmer than the Garrison Dam discharge (Plates 126 -129). The lower summer temperature differences in 2006, 2007, and 2008 are attributed to the full implementation of the short-term water quality management measures at Garrison Dam.

5.3.5.2 Water Temperatures Monitored in the Reach from Garrison Dam to Bismarck, ND in 2005, 2006, and 2007

As part of their fisheries management program, the North Dakota Game and Fish Department (NDGFD) monitored water temperatures in the Missouri River from Garrison Dam (RM1389) to Beaver

Bay (RM1259). Sites monitored in 2005 (June through September) included Stanton (RM1372), Burnt Creek (RM1322), Bismarck (RM1315), Fox Island (RM1312), and Beaver Bay (RM1259). Sites monitored in 2006 (May through September) included Stanton (RM1372), Washburn (RM1355), Wilton (RM1344), Burnt Creek, and North Beaver (RM1260). Sites monitored in 2007 (May through September) included Stanton (RM1372), Washburn (RM1355), Wilton (RM1344), and Bismarck (RM1315). Temperature monitors that were deployed by the NDGFD in 2008 failed and no data were recorded. Plates 130 through 132, respectively, plot mean daily water temperatures monitored in the Missouri River downstream from Garrison Dam in 2005, 2006, and 2007.

5.3.6 MANAGEMENT OF COLDWATER FISHERY HABITAT IN GARRISON RESERVOIR

5.3.6.1 Implementation of Short-term Water Quality Management Measures to Preserve Coldwater Fishery Habitat in Garrison Reservoir

The potential impact of implementing the short-term water quality management measures on preserving coldwater fishery habitat in Garrison Reservoir during the summers of 2005, 2006, 2007, and 2008 was estimated by comparing the quantity of water meeting coldwater conditions (i.e., ≤ 15°C and ≥ 5 mg/l dissolved oxygen) that was discharged through each of the dam's five penstocks. The water quality conditions monitored in penstocks 1, 2, and 3 were compared to penstocks 4 and 5. The water quality conditions monitored in penstocks 4 and 5 were taken to be the water quality conditions that would have occurred in penstocks 1, 2, and 3 if the plywood barriers were not in place. Installation of the plywood barriers on Units 2 and 3 was completed on July 22, 2005 and was completed on Unit 1 on May 19, 2007. During the summers of both 2005 and 2006, most of the water discharged through penstocks 4 and 5 prior to September 1 met coldwater habitat conditions, while almost all the water discharged through penstocks 2 and 3 did not (i.e., water was warmer than 15°C). During the summers of 2007 and 2008, most of the water discharged through penstocks 4 and 5 prior to September 1 met coldwater habitat conditions, while almost all the water discharged through penstocks 1, 2, and 3 did not (i.e., water was warmer than 15°C). This resulted in a potential saving of coldwater habitat in Garrison Reservoir of about 379,390 acre-ft in 2005, about 1,021,150 acre-ft in 2006, about 827,928 acre-ft in 2007, and about 794,850 acre-ft in 2008. All of the potential savings of coldwater habitat occurred prior to early September. After early September, water temperatures in all the penstocks were above 15°C due to the downward expansion of the epilimnion in Garrison Reservoir.

5.4 OAHE

5.4.1 BACKGROUND INFORMATION

5.4.1.1 Project Overview

Oahe Dam is located on the Missouri River at RM 1072.3 in central South Dakota, 6 miles northwest of Pierre, SD. The closing of Oahe Dam in 1958 resulted in the formation of Oahe Reservoir (Lake Oahe). When full, the reservoir is 231 miles long, covers 374,000 acres, and has 2,250 miles of shoreline. Table 5.8 summarizes how the surface area, volume, mean depth, and retention time of Oahe Reservoir vary with pool elevations. Although still experiencing lower pool levels due to lingering drought conditions, the reservoir did recover to a pool elevation of 1592.9 at the end of December 2008. This is 14.6 feet below the top of the Carryover Multiple Use Zone (1607.5 ft-msl). Major inflows to the reservoir are the Missouri and Cheyenne Rivers. Water discharged through Oahe Dam for power production is withdrawn from Oahe Reservoir at elevation 1524 ft-msl, approximately 114 feet above the reservoir bottom.

Table 5.8. Surface area, volume, mean depth, and retention time of Oahe Reservoir at different pool elevations based on 1989 survey.

Elevation (Feet-msl)	Surface Area (Acres)	Volume (Acre-Feet)	Mean Depth (Feet)*	Retention Time (Years)**
1620	374,135	23,136,960	61.8	1.33
1615	350,960	21,323,520	60.8	1.23
1610	325,765	19,630,460	60.3	1.13
1605	300,030	18,068,750	60.2	1.04
1600	281,010	16,618,390	59.1	0.96
1595	260,715	15,265,460	58.6	0.88
1590	245,190	14,002,600	57.1	0.81
1585	229,085	12,816,650	55.9	0.74
1580	213,150	11,711,030	54.9	0.67
1575	196,915	10,686,750	54.3	0.62
1570	182,933	9,737,896	53.2	0.56
1565	168,523	8,859,708	52.6	0.51
1560	155,510	8,049,792	51.8	0.46
1555	141,688	7,308,917	51.6	0.42
1550	133,628	6,622,830	49.6	0.38
1545	124,869	5,976,361	47.9	0.34
1540	116,560	5,373,030	46.1	0.31

Average Annual Inflow (1967 through 2007) = 18.10 Million Acre-Feet
Average Annual Outflow: (1967 through 2007) = 17.36 Million Acre-Feet
* Mean Depth = Volume ÷ Surface Area.
** Retention Time = Volume ÷ Average Annual Outflow.
Note: Exclusive Flood Control Zone (elev. 1620-1617 ft-msl), Annual Flood Control and Multiple Use Zone (elev. 1617-1607.5 ft-msl), Carryover Multiple Use Zone (elev. 1607.5-1540 ft-msl), and Permanent Pool Zone (elev. 1540-1415 ft-msl). All elevations are in the NGVD 29 datum.

Oahe Reservoir and Dam are authorized for the purposes of flood control, recreation, fish and wildlife, hydroelectric power production, water supply, water quality, navigation, and irrigation. Over the period 1967 through 2008, the seven generating units at Oahe Dam have produced an annual average 2.640 million mega-watt hours (MWh) of electricity, which has a current revenue value of approximately $40 million. The lingering drought in the interior western United States has curtailed releases and power production at the Missouri River mainstem system projects, including Oahe. Power production at the Oahe Dam generating units averaged an annual 1.344 MWh over the 5-year period 2004 through 2008. Habitat for one endangered species, interior least tern, and one threatened species, piping plover, occurs within the project area. Oahe Reservoir is used as a water supply by the town of Fort Yates, North Dakota, and the towns of Bear Creek, Blackfoot, Bridger, Cherry Creek, Dupree, Eagle Butte, Faith, Gettysburg, Green Grass, Iron Lightning, Lantry, LaPlante, Mobridge, Promise, Red Elm, Red Schaffold, Swiftbird, Thunder Butte, Wakpala, and White Horse, SD, as well as some individual cabins. The reservoir is an important recreational resource and a major visitor destination in South Dakota.

5.4.1.2 Water Quality Standards Classifications and Section 303(d) Listings

5.4.1.2.1 Oahe Reservoir

Under normal pool levels, Oahe Reservoir runs along the Missouri River from approximately RM1072 to RM1290, and crosses the North Dakota/South Dakota border which is at RM1232. Therefore under normal pools about 25 and 75 percent of the length of the reservoir is respectively in North Dakota and South Dakota. Water quality standards from each State respectively apply to the portion of the reservoir in each state.

The State of North Dakota has classified Oahe Reservoir as a Class 1 lake. As such, the reservoir is to be protected for a coldwater fishery; swimming, boating, and other water recreation; irrigation; stock watering; wildlife; and municipal or domestic use after appropriate treatment. Pursuant to Section 303(d) of the Federal CWA, North Dakota has not placed the Oahe Reservoir on the State's list of impaired waters. The State of North Dakota has issued a fish consumption advisory for Oahe Reservoir due to mercury concerns.

South Dakota has classified the Missouri River impoundments within the State as flowing streams and not reservoirs (South Dakota Administrative Rules 74:51:01:43). The following water quality-dependent beneficial uses have been designated for Oahe Reservoir in South Dakota's water quality standards: domestic water supply waters, coldwater permanent fish life propagation waters, immersion recreation waters, limited-contact recreation waters, commerce and industry waters, agricultural water supply (i.e., irrigation and stock watering), and fish and wildlife propagation. The State of South Dakota has not placed the reservoir on the State's Section 303(d) list of impaired waters and has not issued a fish consumption advisory for the reservoir.

5.4.1.2.2 Missouri River Downstream of Oahe Dam

The following beneficial uses have been designated by South Dakota in their water quality standards for the Missouri River: recreation (i.e., immersion and limited-contact), coldwater permanent fish life propagation, domestic water supply, agricultural water supply (i.e., irrigation and stock watering), commerce and industrial waters, and fish and wildlife propagation. The State of South Dakota has not placed the river on its Section 303(d) list of impaired waters and has not issued a fish consumption advisory for the river.

5.4.1.3 Ambient Water Quality Monitoring

The District has monitored water quality conditions at the Oahe Project since the late 1970's. Water quality monitoring locations have included sites on the reservoir and on the inflow to and outflow from the reservoir. A 3-year intensive water quality survey was completed at the Oahe Project in 2007, and the findings of the intensive survey are available in the separate report, "Water Quality Conditions Monitored at the Corps' Oahe Project in South Dakota during the 3-year period 2005 through 2007" (USACE, 2008). Figure 5.5 shows the location of sites at the Oahe Project that have been monitored by the District for water quality during the past 5 years (i.e., 2004 through 2008). Water quality monitoring upstream of Mobridge, South Dakota (i.e., RM1196) was not conducted during the 5-year period. Drought conditions and low pool levels during this period resulted in the reservoir's upstream boundary receding to near the North Dakota/South Dakota border. The District plans to conduct water quality monitoring upstream of RM1196 when normal pool levels return. The near-dam location (i.e., site OAHLK1073A) has been continuously monitored since 1980.

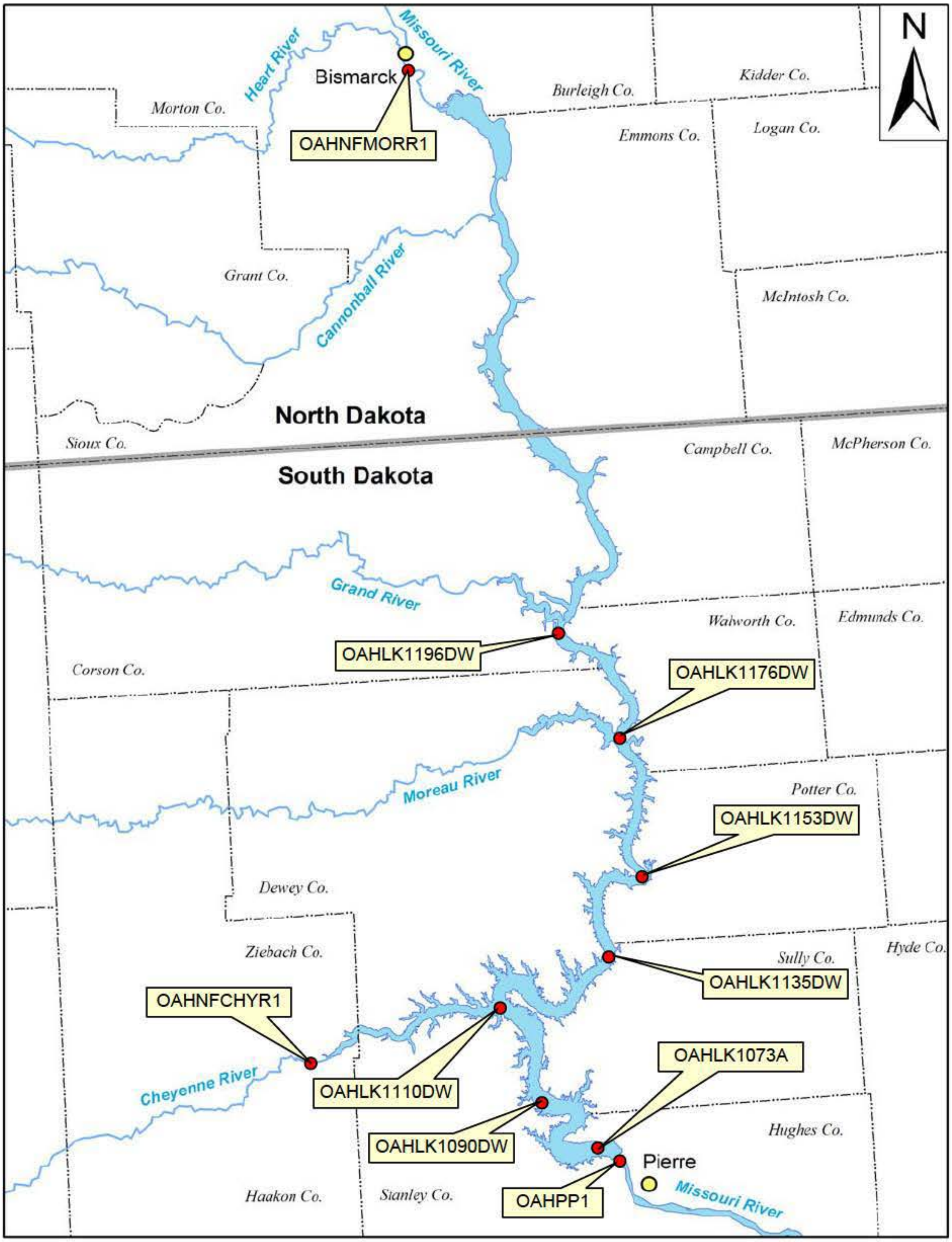

Figure 5.5. Location of sites where water quality monitoring was conducted by the District at the Oahe Project during the period 2004 through 2008.

5.4.2 WATER QUALITY IN OAHE RESERVOIR

5.4.2.1 Existing Water Quality Conditions (2004 through 2008)

5.4.2.1.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

Water quality conditions that were monitored in Oahe Reservoir at sites OAHLK1073A, OAHLK1090DW, OAHLK1110DW, OAHLK1135DW, OAHLK1153DW, OAHLK1176DW, and OAHLK1196DW from May through September during the 5-year period 2004 through 2008 are summarized in Plates 133 through 139. A review of these results indicated possible water quality concerns regarding water temperature and dissolved oxygen for the support of Coldwater Permanent Fish Life Propagation. Water temperatures in the epilimnion of the reservoir regularly exceed 18.3°C in the summer, while temperatures in the hypolimnion are less than 18.3°C. Dissolved oxygen levels in the hypolimnion continually degrade along the reservoir bottom as summer progresses and fall below 7.0 mg/l in late summer (i.e., occurred in non-spawning area outside the spawning season for coldwater species). During the 5-year period, dissolved oxygen levels remained above 6.0 mg/l in the hypolimnion in the area of the reservoir near Oahe Dam (Plates 133 and 134). Dissolved oxygen concentrations regularly fell below 6 mg/l in the middle and upstream reaches of the hypolimnion (Plates 135 - 138). As the summer progressed, conditions of lower dissolved oxygen moved up from the reservoir bottom into the hypolimnion. During the 4-year period 2005 through 2008, a hypolimnion did not form in the upstream reaches of the reservoir near Mobridge, South Dakota (Plate 139); seemingly due to the shallowness of the reservoir and mixing of the water column. Conditions supportive of Coldwater Permanent Fish Life Propagation (i.e., water temperature ≤18.3°C and dissolved oxygen ≥ 6 mg/l) were present in 100, 100, 88, 55, 53, 25, and 24 percent of the depth-profile measurements respectively taken at sites OAHLK1073A, OAHLK1090DW, OAHLK1110DW, OAHLK1135DW, OAHLK1153DW, OAHlk1176DW, and OAHLK1196DW (Plates 133 - 139). The lowest dissolved oxygen concentration measured during the 5-year period at the seven sites was 2.5 mg/l, and occurred at site OAHLK1153DW on August 14, 2007.

5.4.2.1.2 Summer Thermal Stratification

5.4.2.1.2.1 2008 Monthly Longitudinal Temperature Contour Plots

Summer thermal stratification of Oahe Reservoir during 2008 is described by the monthly longitudinal temperature contour plots based on depth-profile temperature measurements taken in May, June, July, August, and September (Plates 140 - 144). The contour plots were constructed along the length of the reservoir. As seen in Plates 140 through 144, water temperature in Oahe Reservoir varies longitudinally from the dam to the reservoir's upper reaches and vertically from the reservoir surface to the bottom. The near-surface water in the upper reaches of the reservoir warms up sooner in the spring than the near-surface water near the dam (Plate 140 and 141). By mid-summer a strong thermocline becomes established in the lower reaches of the reservoir, and the near-surface waters of the entire reservoir above the thermocline are a fairly uniform temperature (Plates 142- 143). As the near-surface waters of the reservoir cool in the late summer, the thermocline is pushed deeper and these wind-mixed upper waters are fairly uniform in temperature (Plate 144). The vertical variation in temperature is most prevalent in the deeper area of the reservoir towards the dam where a strong thermocline becomes established during the summer. The shallower upper reaches of Oahe Reservoir do not exhibit much vertical variation of temperature during mid to late summer as wind action allows for complete mixing of the water column.

5.4.2.1.2.2 Near-Dam Temperature Depth-Profile Plots

Existing summer thermal stratification of Oahe Reservoir at the deep water area near the dam is described by the depth-profile temperature plots measured over the 5-year period 2004 through 2008. Depth-profile temperature plots measured during the summer months were compiled (Plate 145). The plotted depth-profile measurements indicate that a significant temperature-depth gradient occurs in Oahe Reservoir in the near-dam lacustrine area during the summer, and a thermocline becomes established at a depth of about 20 meters (Plate 145).

5.4.2.1.3 Summer Dissolved Oxygen Conditions

5.4.2.1.3.1 2008 Monthly Longitudinal Dissolved Oxygen Contour Plots

Dissolved oxygen longitudinal contour plots were constructed along the length of Oahe Reservoir based on depth-profile measurements taken in May, June, July, August, and September of 2008 (Plates 146 - 150). During the summer of 2008, dissolved oxygen conditions in Oahe Reservoir varied longitudinally from the dam to the reservoir's upper reaches and vertically from the reservoir surface to the bottom (Plates 146 - 150). Dissolved oxygen levels below 6 mg/l first appeared near the reservoir bottom in the middle reaches of the reservoir in August (Plate 149). As the summer progressed, dissolved oxygen concentrations below 6 mg/l expanded along the bottom in the middle reaches of the reservoir (Plate 150). Near-bottom dissolved oxygen concentrations at the dam remained above 6 mg/l (Plate 150). The occurrence of low dissolved oxygen concentrations in the near-bottom water of the middle reaches of Oahe Reservoir is attributed to the increased allochthonous organic loading in the transition zone of the reservoir and the lesser hypolimnetic volume available for assimilation of the oxygen demand. As this material decomposes, a "pool" of water with low dissolved oxygen levels accumulates near the bottom in this area of the reservoir. Decomposition of autochthonous organic matter also occurs in the lacustrine zone and results in dissolved oxygen degradation as the summer progresses, although at a slower rate than what occurs in the transition zone. The recovery of near-bottom dissolved oxygen concentrations to saturation levels takes longer in the deeper water nearer the dam because of the time needed for thermal stratification to breakdown and mixing within the water column to occur in the deeper water.

5.4.2.1.3.2 Near-Dam Dissolved Oxygen Depth-Profile Plots

Existing summer dissolved oxygen conditions in Oahe Reservoir at the deep-water area near the dam are described by the depth-profile dissolved oxygen plots measured over the 5-year period 2004 through 2008. Depth-profile dissolved oxygen plots measured during the summer months at site OAHLK1073A were compiled (Plate 151). Dissolved oxygen levels exhibited a significant gradient with depth and tended toward a negative heterograde to orthograde vertical distribution (Plate 151). During the period of 2004 through 2008, dissolved oxygen concentrations in the lower hypolimnion did not fall below 6 mg/l. The lowest dissolved oxygen concentration measured at this site over the past 5 years was 6.0 mg/l, which was measured at the reservoir bottom on September 14, 2005.

5.4.2.1.4 Occurrence of Coldwater Permanent Fish Life Propagation Habitat in Oahe Reservoir

The most crucial period for the support of Coldwater Permanent Fish Life Propagation (CPFLP) habitat in Oahe Reservoir is when the reservoir begins to cool in late summer. As the thermocline moves deeper, the volume of the coldwater hypolimnion continues to decrease while the expanding epilimnion may not have cooled enough to be supportive of CPFLP habitat. At the same time, hypolimnetic dissolved oxygen concentrations are approaching their maximum degradation and low dissolved oxygen levels are moving upward from the reservoir bottom and "pinching off" coldwater habitat from below. This situation continues to worsen until the epilimnion cools enough to be supportive of CPFLP habitat

and the reservoir eventually experiences fall turnover. The volume of the hypolimnion (i.e., CPFLP habitat) occurring in Oahe Reservoir during the summer decreases with lower pool levels.

The occurrence of CPFLP habitat (i.e., water temperature ≤ 18.3°C and dissolved oxygen ≥ 6 mg/l) in Oahe Reservoir was estimated from collected water temperature and dissolved oxygen depth-profile measurements and defined reservoir elevation and volume relationships. Plate 152 displays a plot of pool elevations and the CPFLP habitat estimated to have been present in Oahe Reservoir during the summers of 2005 through 2008.

The occurrence of coldwater habitat in Oahe Reservoir is believed to be highly dependent on pool elevation. Since coldwater habitat only occurs in the hypolimnion of the reservoir during the summer, the size of the hypolimnion will directly determine the amount of coldwater habitat potentially available. The upper extent of the hypolimnion is delineated by the thermocline (i.e., zone of rapid temperature decline) which separates the colder hypolimnion from the warmer, less dense water of the epilimnion. Depending on climatic factors, the thermocline in an individual reservoir will generally be established at a similar depth from year to year. Therefore, a greater hypolimnetic volume will tend to occur under higher pool elevations and a lesser hypolimnetic volume will tend to occur under lower pool elevations. The pool elevation in late-spring and early summer when the thermocline first becomes established is especially important as later changes in pool elevations are mitigated somewhat by the stratification already established. A larger hypolimnetic volume also has a greater assimilative capacity for oxygen demanding materials which can degrade dissolved oxygen levels in the hypolimnion below the CPFLP habitat standard of 6 mg/l.

The relationship between the occurrence of CPFLP habitat and pool elevation is can be seen in the CPFLP habitat estimated to have occurred in Oahe Reservoir during 2005 through 2008 (Plate 152). The year with the highest pool elevation (i.e., 2008) had the highest estimated occurrence of CPFLP habitat. The years with the lower pool elevations (i.e., 2005, 2006, and 2007) generally had the lowest estimated occurrence of CPFLP habitat.

5.4.2.1.5 Water Clarity

5.4.2.1.5.1 Secchi Transparency

Figure 5.6 displays a box plot of the Secchi depth transparencies measured along Oahe Reservoir at the four sites OAHLK1196DW, OAHLK1153DW, OAHLK1110DW, and OAHLK1073A during the 4-year period 2005 through 2008. Secchi depth transparency increased in a downstream direction from the upper reaches of the reservoir to near the dam (Figure 5.6). This is attributed to suspended sediment in the inflowing Missouri River settling out in the reservoir as current velocities slow. The surface waters near Oahe Dam are significantly clearer than the upstream regions of the reservoir. Under the conditions that were monitored during the 2005 to 2008 period, it appears that site OAHLK1196DW was in the riverine zone; site OAHLK1153DW was in the transition zone; site OAHLK1110DW was in the boundary area between the transition and lacustrine zones, and possibly impacted by the inflow of the Cheyenne River; and site OAHLK1073A was in the lacustrine zone of the reservoir.

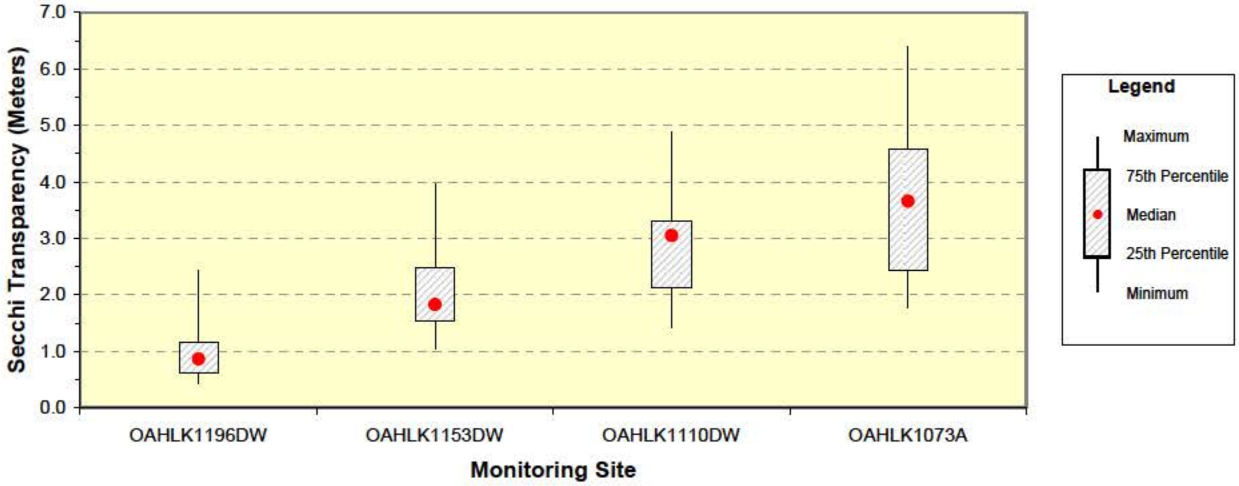

Figure 5.6. Box plot of Secchi transparencies measured in Oahe Reservoir during the 4-year period 2005 through 2008.

5.4.2.1.5.2 Turbidity

Monthly (i.e., May, June, July, August, and September) longitudinal contour plots were prepared from the depth-profile turbidity measurements taken at sites OAHLK1073A, OAHLK1110DW, OAHLK1153DW, OAHLK1196DW, and OAHNFMORR1 during 2008 (Plates 153 - 157). As seen in Plate 153, turbidity levels in Oahe Reservoir in the spring vary longitudinally from the dam to the reservoir's upstream reaches. Turbidity levels measured in the upstream reaches of Oahe Reservoir in the spring, although higher than the levels measured near the dam, were of a lower magnitude. Turbidity levels measured in Oahe Reservoir did not exhibit appreciable vertical variation (Plates 153 - 157).

5.4.2.1.6 Comparison of Near-Surface and Near-Bottom Water Quality Conditions

Paired near-surface and near-bottom water quality samples collected from Oahe Reservoir during the summer were compared. Near-surface conditions were represented by samples collected within 2-meters of the reservoir surface, and near-bottom conditions were represented by samples collected within 2-meters of the reservoir bottom. The compared samples were collected at the near-dam site OAHLK1073A during the 5-year period 2004 through 2008. During the period a total of 18 paired samples were collected monthly from June through September. Box plots were constructed to display the distribution of the paired near-surface and near-bottom measurements for the following parameters: water temperature, dissolved oxygen, oxidation-reduction potential (ORP), pH, alkalinity, total organic carbon (TOC), total Kjeldahl nitrogen (TKN), total ammonia, and total phosphorus (Plate 158). A paired two-tailed t-test was used to determine if the sampled near-surface and near-bottom conditions for the paired samples were significantly different ($\alpha = 0.05$). The sampled near-surface and near-bottom conditions were significantly different for water temperature, dissolved oxygen, ORP, pH, and alkalinity. Parameters that were significantly lower in the near-bottom water of Oahe Reservoir included: water temperature ($p < 0.001$), dissolved oxygen ($p < 0.05$), and pH ($p < 0.001$). Parameters that were significantly higher in the near-bottom water included: ORP ($p < 0.001$) and alkalinity ($p < 0.001$).

5.4.2.1.7 Reservoir Trophic Status

Trophic State Index (TSI) values for Oahe Reservoir were calculated from monitoring data collected during the 4-year period 2005 through 2008 (Table 5.9). The calculated TSI values indicate that the lacustrine zone of the reservoir (i.e., sites OAHLK1073A and OAHLK1110DW) is mesotrophic, the transition zone (i.e., site OAHLK1153DW) is moderately eutrophic, and the riverine zone (i.e., site OAHLK11961DW) is eutrophic. However, it is noted that the calculated average TSI value for the riverine zone is greatly influenced by the low water clarity in this part of the reservoir. This lack of water clarity is largely attributed to suspended inorganic material delivered to the reservoir by the Missouri River. Thus, the higher TSI values in the riverine zone seemingly are not indicative of increased algal growth associated with nutrient enrichment.

Table 5.9. Mean Trophic State Index (TSI) values calculated for Oahe Reservoir. TSI values are based on monitoring at the identified four sites during 4-year period 2005 through 2008.

Monitoring Site	Mean – TSI (Secchi Depth)	Mean – TSI (Total Phos.)	Mean – TSI (Chlorophyll)	Mean – TSI (Average)
OAHLK1073A	41	51	44	46
OAHLK1110DW	45	54	43	47
OAHLK1153DW	51	56	50	52
OAHLK1196DW	64	55	54	58

Note: See Section 4.1.4 for discussion of TSI calculation.

5.4.2.1.8 Phytoplankton Community

Phytoplankton grab samples collected from Oahe Reservoir at sites OAHLK10730A, OAHLK1110DW, OAHLK1153DW, and OAHLK1196DW during the spring and summer of the 5-year period 2004 through 2008 are summarized in Plates 159 through 162. The following seven taxonomic divisions were represented by taxa collected in the phytoplankton samples: Bacillariophyta (Diatoms), Chlorophyta (Green Algae), Chrysophyta (Golden Algae), Cryptophyta (Cryptomonad Algae), Cyanobacteria (Blue-Green Algae), Pyrrophyta (Dinoflagellate Algae), and Euglenophyta (Euglenoid Algae). The general prevalence of these taxonomic divisions in the reservoir, based on taxa occurrence, were Bacillariophyta > Chlorophyta/Cyanobacteria > Cryptophyta > Pyrrophyta > Chrysophyta > Euglenophyta. The diatoms were generally the most abundant algae based on percent composition (Plates 159 - 162). The Shannon-Weaver genera diversity indices calculated for the 74 phytoplankton samples collected at the four sites ranged from 0.55 to 2.53 and averaged 1.49 at site OAHLK1073A, 1.57 at site OAHLK1110DW, 1.45 at site OAHLK1153DW, and 1.54 at site OAHLK1196DW. Dominant phytoplankton genera sampled at the four sites in 2008 (i.e., genera comprising more than 10% of the total biovolume of at least one sample collected in 2008) included the the Bacillariophyta *Asterionella*, *Fragilaria, and Tablellaria*; Chlorophyta *Chlamydomonas* and *Staurastrums*; and Cryptophyta *Rhodomonas*. No concentrations of microcystin above 1 ug/l were monitored in Oahe Reservoir during 2004 through 2008.

5.4.2.1.9 Impairment of Designated Water Quality Beneficial Uses

Based on the State of South Dakota’s impairment assessment methodology (Section 4.1.6.4), the water quality conditions monitored in Oahe Reservoir during the 5-year period 2004 through 2008 did not indicate any impairment of designated water quality beneficial uses.

5.4.2.2 Water Quality Trends (1980 through 2008)

Water quality trends over the 29-year period of 1980 through 2008 were determined for Oahe Reservoir for Secchi depth, total phosphorus, chlorophyll *a*, and TSI (i.e., trophic status). The assessment was based on near-surface sampling of water quality conditions in the reservoir during the months of May through September at the near-dam, ambient monitoring site (i.e., site OAHLK1073A). Plate 164 displays a scatter-plot of the collected data for the four parameters, a linear regression trend line, and the significance of the trend line (i.e., $\alpha = 0.05$). For the assessment period, Oahe Reservoir exhibited a significant trend for TSI (increasing) (Plate 164). No significant trends were detected for Secchi depth, total phosphorus, or chlorophyll *a* (Plate 164). Over the 29-year period, the reservoir has generally remained in a mesotrophic state (Plate 164).

5.4.3 EXISTING WATER QUALITY CONDITIONS OF THE MISSOURI RIVER INFLOW TO OAHE RESERVOIR

5.4.3.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

The water quality conditions that were monitored in the Missouri River at Bismarck, ND (i.e., site OAFNFMORR1) during the 4-year period 2005 through 2008 are summarized in Plate 165. A review of these results indicated no major water quality concerns.

5.4.3.2 Missouri River Inflow Nutrient Flux Conditions

Nutrient flux rates for the Missouri River inflow to Oahe Reservoir during the 4-year period 2005 through 2008 were calculated based on water quality samples collected near Bismarck, ND (i.e. site OAHNFMORR1) and the estimated flow conditions at the time of sample collection (Table 5.10). The maximum nutrient flux rates are attributed to greater nonpoint-source nutrient loadings associated with runoff conditions.

Table 5.10. Summary of nutrient flux rates (kg/sec) calculated for the Missouri River at Bismarck, ND during April through September over the 4-year period 2005 through 2008.

Statistic	Flow (cfs)	Total Ammonia N (kg/sec)	Total Kjeldahl N (kg/sec)	Total NO_3-NO_2 N (kg/sec)	Total Phosphorus (kg/sec)	Dissolved Phosphorus (kg/sec)	Total Organic Carbon (kg/sec)
No. of Obs.	21	21	21	20	21	21	20
Mean*	15,961	0.0094	0.1277	0.0284	0.0401	0.0107	1.3294
Median	15,525	n.d.	0.1348	0.0298	0.0170	0.0079	1.2897
Minimum	10,564	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
Maximum	26,800	0.0492	0.3369	0.0632	0.1594	0.0780	2.2766

n.d. = Nondetectable.

Note: Nondetect values set to 0 for flux calculations.

5.4.3.3 Continuous Water Temperature Monitoring of the Missouri River at USGS Gage Site 06342500 at Bismarck, North Dakota

Through an agreement with the USGS, a water temperature monitoring probe was added to the USGS's gage (06342500) on the Missouri River near Bismarck, ND (i.e., site OAHNFMORR1). Beginning in 2005, water temperature measurements were recorded at the site. Plates 166, 167, 168, and 169, respectively, plot mean daily water temperature and river discharge determined for 2005, 2006, 2007, and 2008.

5.4.4 WATER QUALITY AT THE OAHE POWERPLANT

5.4.4.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

Plate 170 summarizes the water quality conditions that were monitored from water discharged through Oahe Dam during 5-year period 2004 through 2008. A review of these results indicated possible water quality concerns regarding temperature for the support of Coldwater Permanent Fish Life Propagation.

Twenty-seven percent of the "grab sample" water temperature measurements taken on the water passed through Oahe Dam exceeded the Coldwater Permanent Fish Life Propagation temperature criterion of 18.3°C. The exceedences of the 18.3°C temperature criterion occurred during the summer. During the summer when Oahe Reservoir is thermally stratified, water temperatures in the epilimnion of the reservoir regularly exceed 18.3°C, while temperatures in the hypolimnion are less than 18.3°C. Water discharged through Oahe Dam for power production is withdrawn from Oahe Reservoir at elevation 1524 ft-msl, approximately 114 feet above the reservoir bottom. Thus, water withdrawn from the reservoir in the summer comes largely from the epilimnion, especially when pool elevations are lower due to drought conditions (see Plates 142 and 143). Because water passed through Oahe Dam during the summer is withdrawn from the epilimnion of the reservoir, the temperature criterion of 18.3°C for the Missouri River and Big Bend Reservoir just downstream of the dam are not being met during the summer when Oahe Reservoir is thermally stratified.

5.4.4.2 Temperature, Dissolved Oxygen, and Dam Discharge Time-Series Plots

Semiannual time-series plots for temperature, dissolved oxygen, and dam discharge monitored at the Oahe powerplant during the 5-year period 2004 December 2008 were constructed. Water temperatures showed seasonal warming and cooling through each calendar year (Plates 171 - 180). Dissolved oxygen levels remained relatively high and stable during the winter, steadily declined through the spring and summer, and steadily increased during the fall (Plates 181 - 190). The lowest dissolved oxygen levels occurred during the late summer period. The higher winter, declining spring, and increasing fall dissolved oxygen concentrations are attributed to decreasing dissolved oxygen solubility with warmer water temperatures. The decreasing dissolved oxygen in the July to September period may also be attributed somewhat to the influence of ongoing degradation of dissolved oxygen in the hypolimnion as the summer progressed. There appeared to be little correlation between discharge rates and measured water temperature and dissolved oxygen concentrations (Plates 171 - 190).

5.4.4.3 Comparison of Monitored Inflow and Outflow Temperatures of the Missouri River at Oahe Reservoir

Plates 191, 192, 193, and 194, respectively, plot the mean daily water temperatures monitored at the Missouri River near Bismarck, ND (site OAHNFMORR1) and the Oahe Dam powerplant (site OAHPP1) for 2005, 2006, 2007, and 2008. Inflow temperatures of the Missouri River to Oahe Reservoir are generally warmer than the outflow temperatures of Oahe Dam during the period of April through June (Plates 191 - 194). Outflow temperatures of the Oahe Dam discharge are generally warmer than the inflow temperatures of the Missouri River during the period of July through March (Plates 191 - 194). A maximum temperature difference occurs in the fall when the Oahe Dam outflow temperature is about 4°C warmer than the Missouri River inflow temperature.

5.5 BIG BEND

5.5.1 BACKGROUND INFORMATION

5.5.1.1 Project Overview

Big Bend Dam is located in central South Dakota on the Missouri River at RM 987.4, 21 miles northwest of Chamberlain, SD. The closing of Big Bend Dam in 1963 resulted in the formation of Big Bend Reservoir (Lake Sharpe). The reservoir, when full, is 80 miles long, covers 61,000 acres, and has 200 miles of shoreline. Table 5.11 summarizes how the surface area, volume, mean depth, and retention time of Big Bend Reservoir vary with pool elevations. The Big Bend powerplant is operated to meet peak power demands for electricity. Generally, weekly flows from Oahe Dam are released at Big Bend Dam, and there is minimal fluctuation in the water level of Big Bend Reservoir. The Annual Flood Control and Multiple Use Zone in the reservoir does not provide for seasonal regulation of flood inflows like the other major upstream Mainstem System projects, but the zone is used for day-to-day and week-to-week power operations. The Corps normally strives to maintain the pool level in the reservoir between elevation 1419 ft-msl and 1421.5 ft-msl. There are no minimum flow requirements below Big Bend Dam, and hourly releases can fluctuate from 0 to 110,000 cfs for peaking power generation. The major inflows to Big Bend Reservoir are the Missouri River and Bad River. Water discharged through Big Bend Dam for power production is withdrawn from the bottom of Big Bend Reservoir at an invert elevation of 1330.0 ft-msl.

Table 5.11. Surface area, volume, mean depth, and retention time of Big Bend Reservoir at different pool elevations based on 1997 survey.

Elevation (Feet-msl)	Surface Area (Acres)	Volume (Acre-Feet)	Mean Depth (Feet)*	Retention Time (Years)**
1430	70,615	2,259,568	32.0	0.1316
1425	63,808	1,923,508	30.1	0.1121
1420	57,007	1,621,484	28.4	0.0945
1415	50,224	1,353,339	26.9	0.0788
1410	43,146	1,119,548	25.9	0.0652
1405	35,694	923,872	25.9	0.0538
1400	31,842	756,297	23.8	0.0441
1395	27,402	608,587	22.2	0.0355
1390	24,659	479,172	19.4	0.0279
1385	21,779	362,729	16.7	0.0211
1380	18,307	262,285	14.3	0.0153
1375	14,856	179,548	12.1	0.0105
1370	11,747	113,160	9.6	0.0066
1365	8,590	62,333	7.3	0.0036
1360	5,449	27,069	5.0	0.0016
1355	2,021	9,373	4.6	0.0005
1350	836	2,445	2.9	0.0001

Average Annual Inflow (1967 through 2007) = 17.34 Million Acre-Feet.
Average Annual Outflow: (1967 through 2007) = 17.16 Million Acre-Feet.
* Mean Depth = Volume ÷ Surface Area.
** Retention Time = Volume ÷ Average Annual Outflow.
Note: Exclusive Flood Control Zone (elev. 1423-1422 ft-msl), Annual Flood Control and Multiple Use Zone (elev. 1422-1420 ft-msl), Carryover Multiple Use Zone (none), and Permanent Pool Zone (elev. 1420-1345 ft-msl). All elevations are in the NGVD 29 datum.

The reservoir and dam are authorized for the purposes of flood control, recreation, fish and wildlife, hydroelectric power production, water supply, water quality, navigation, and irrigation. The powerplant has eight generating units that produce an annual average 0.976 million megawatt hours of electricity, valued in excess of $16 million in revenue. Past drought conditions in the interior western United States has curtailed releases and power production at the Missouri River mainstem system projects, including Big Bend. Power production at the Big Bend Dam generating units averaged an annual 0.589 MWh over the 5-year period 2004 through 2008. Habitat for one endangered species, interior least tern, and one threatened species, piping plover, occurs within the project area. Big Bend Reservoir is used as a water supply by the cities of Pierre, Fort Pierre, Fort Thompson, and Lower Brule, South Dakota. The reservoir is an important recreational resource.

5.5.1.2 Water Quality Standards Classification and Section 303(d) Listings

5.5.1.2.1 Big Bend Reservoir

South Dakota has classified the Missouri River impoundments within the State as flowing streams and not reservoirs (South Dakota Administrative Rules 74:51:01:43). The following water quality-dependent beneficial uses have been designated for Big Bend Reservoir in South Dakota's water quality standards: domestic water supply waters, coldwater permanent fish life propagation waters, immersion recreation waters, limited-contact recreation waters, commerce and industry waters, agricultural water supply (i.e., irrigation and stock watering), and fish and wildlife propagation. The State of South Dakota has recently removed Big Bend Reservoir from the State's Section 303(d) list of impaired waters. The reservoir was previously listed as impaired due to accumulated sediment from the Bad River watershed. A total maximum daily load (TMDL) was developed and is being implemented to address this concern, resulting in the delisting of Big Bend Reservoir. South Dakota has not issued a fish consumption advisory for the reservoir.

5.5.1.2.2 Missouri River Downstream of Big Bend Dam

The State of South Dakota has designated the following water quality-dependent beneficial uses for the Missouri River downstream of Big Bend Dam: domestic water supply waters, warmwater permanent fish life propagation waters, immersion recreation waters, limited-contact recreation waters, commerce and industry waters, agricultural water supply (i.e., irrigation and stock watering), and fish and wildlife propagation. Big Bend Dam is the demarcation point between coldwater and warmwater use designation on the Missouri River system in South Dakota. Therefore, the designated use of Warmwater Permanent Fish Life Propagation applies to the Big Bend Dam tailwaters instead of the Coldwater Permanent Fish Life Propagation use that applies to Big Bend Reservoir. South Dakota has not issued a fish consumption advisory for the Missouri River downstream of Big Bend Dam.

5.5.1.2.3 Ambient Water Quality Monitoring

The District has monitored water quality conditions at the Big Bend Project since the late 1970's. Water quality monitoring locations have included sites on the reservoir and on the inflow to and outflow from the reservoir. A 3-year intensive water quality survey scheduled for 2008 through 2010 is currently underway at the Big Bend Project. The water quality conditions of the Oahe Dam discharge are taken to represent the inflow water quality conditions to Big Bend Reservoir. Figure 5.7 shows the location of sites at the Big Bend Project that have been monitored for water quality during the past 5 years (i.e., 2004 through 2008). The near-dam location (i.e., site BBDLK0987A) has been continuously monitored since 1980.

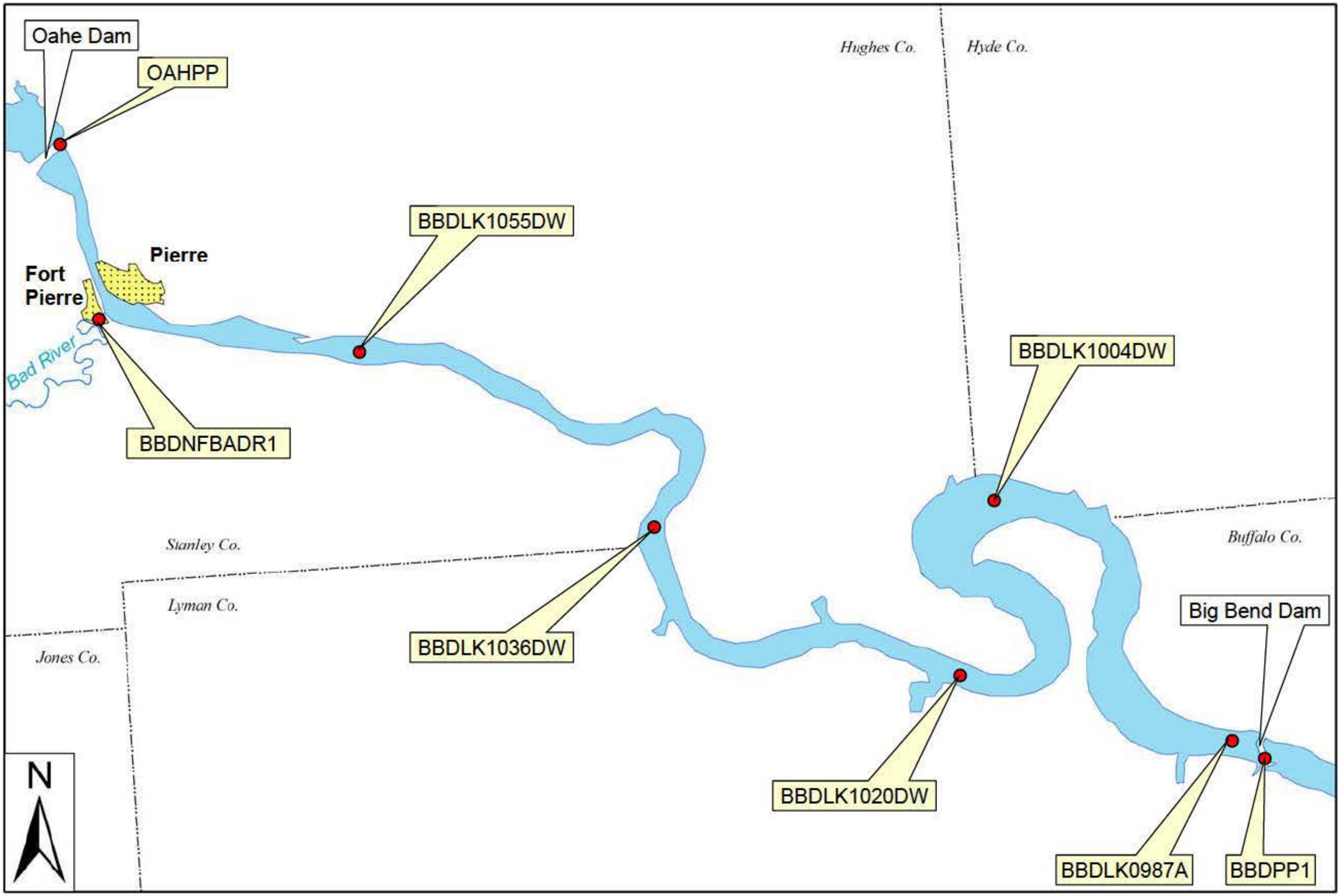

Figure 5.7. Location of sites where water quality monitoring was conducted by the District at the Big Bend Project during the period 2004 through 2008.

5.5.2 WATER QUALITY IN BIG BEND RESERVOIR

5.5.2.1 <u>Existing Water Quality Conditions (2004 through 2008)</u>

5.5.2.1.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

Water quality conditions that were monitored in Big Bend Reservoir at sites BBDLK0987A, BBDLK1004DW, BBDLK1020DW, BBDLK1036DW, and BBDLK1005DW from May through September during the 5-year period 2004 through 2008 are summarized in Plates 195 through 199. A review of these results indicated water quality concerns regarding water temperature and dissolved oxygen for the support of Coldwater Permanent Fish Life Propagation (CPFLP). Due to its shallowness, a hypolimnion rarely forms in Big Bend Reservoir and water temperatures throughout the reservoir regularly exceed 18.3°C in the summer. Dissolved oxygen levels near the bottom of the reservoir occasionally fall below 6.0 mg/l during the summer. The lowest dissolved oxygen concentration measured during the 5-year period at the five sites was 3.1 mg/l, and occurred at site BBDLK0987A on July 13, 2005.

5.5.2.1.2 Summer Thermal Stratification

5.5.2.1.2.1 2008 Monthly Longitudinal Temperature Contour Plots

Summer thermal stratification of Big Bend Reservoir during 2008 is described by the monthly longitudinal temperature contour plots based on depth-profile temperature measurements taken in June, July, August, and September (Plates 200 - 203). The contour plots were constructed along the length of the reservoir. As seen in Plates 200 through 203, water temperature in Big Reservoir varies longitudinally from the dam to the reservoir's upstream reaches and vertically from the reservoir surface to the bottom. Cooler water is typically discharged from Oahe Dam from late-spring through mid-summer which quickly warms in Big Bend Reservoir (Plates 200 - 202). Although some summer thermal stratification of Big Bend Reservoir can occur, the relative shallowness, short retention time, and bottom withdrawal of the reservoir seemingly inhibit the formation of a strong thermocline and long-lasting stratification during the summer. Since Big Bend Reservoir ices over in the winter and exhibits minor thermal stratification in the summer it appears to fit the definition of a discontinuous cold polymictic lake (Wetzel, 2001). Wetzel (2001) identifies lakes as discontinuous cold polymictic if they are ice-covered part of the year and ice-free above 4°C during the warm season, and exhibit thermal stratification during the warm period for periods of several days to weeks but with irregular interruption by mixing.

5.5.2.1.2.2 Near-Dam Temperature Depth-Profile Plots

Existing summer thermal stratification of Big Bend Reservoir at the deep water area near the dam is described by the depth-profile temperature plots measured over the 5-year period 2004 through 2008. Depth-profile temperature plots measured during the summer months were compiled (Plate 204). No significant temperature-depth gradient is apparent in Big Bend Reservoir in the near-dam area during the summer (Plate 204).

5.5.2.1.3 Summer Dissolved Oxygen Conditions

5.5.2.1.3.1 2008 Monthly Longitudinal Dissolved Oxygen Contour Plots

Dissolved oxygen longitudinal contour plots were constructed along the length of Big Bend Reservoir based on depth-profile measurements taken in June, July, August, and September of 2008 (Plates 205 - 208). During the summer of 2008, dissolved oxygen conditions in Big Bend Reservoir

varied longitudinally from the dam to the reservoir's upstream reaches and vertically from the reservoir surface to the bottom (Plates 205 - 208). Dissolved oxygen levels below 6 mg/l first appeared at the reservoir bottom near the dam in July (Plate 206). Dissolved oxygen concentrations below 6 mg/l expanded along the reservoir bottom in the area near the dam, and concentrations approached 3 mg/l at the dam (Plate 207). Dissolved oxygen levels recovered to near saturation levels throughout Big Bend Reservoir by mid-September (Plate 208). There appears to have been enough thermal stratification in Big Bend Reservoir during the summer of 2008 to allow for the degradation of dissolved oxygen levels in a small area near the dam.

5.5.2.1.3.2 Near-Dam Dissolved Oxygen Depth-Profile Plots

Existing summer dissolved oxygen conditions in Big Bend Reservoir at the deep-water area near the dam are described by the depth-profile dissolved oxygen plots measured over the 5-year period 2004 through 2008. Depth-profile dissolved oxygen plots measured during the summer months at site BBDLK0987A were compiled (Plate 209). Dissolved oxygen levels below 6 mg/l regularly occurred near the bottom of the reservoir, and levels near the reservoir bottom approached 3 mg/l on two occasions.

5.5.2.1.4 Occurrence of Coldwater Permanent Fish Life Propagation Habitat in Big Bend Reservoir

The most crucial period for the support of Coldwater Permanent Fish Life Propagation (CPFLP) habitat in Big Bend Reservoir is during mid-summer. Monitoring indicates that the reservoir is probably discontinuous polymictic with a hypolimnion forming on an irregular basis. This results in complete mixing and warming of the water column above 18.3°C during the summer. When stratification does persist, dissolved oxygen degradation to levels below 6 mg/l occurs near the reservoir bottom in deeper waters near the dam.

The occurrence of CPFLP habitat (i.e., water temperature ≤ 18.3°C and dissolved oxygen ≥ 6 mg/l) in Big Bend Reservoir was estimated from collected water temperature and dissolved oxygen depth-profile measurements. Conditions supportive of CPFLP were present in 40, 25, 50, 50, and 25 percent of the depth-profile measurements respectively taken at sites BBDLK0987A, BBDLK1004DW, BBDLK1020DW, BBDLK1036DW, and BBDLK1005DW (Plates 195 - 199). Conditions supportive of CPFLP were not present anywhere in the reservoir during the months of July and August. Ambient water temperatures in Big Bend Reservoir do not appear to be cold enough to support CPFLP, as defined by State water quality criteria, during mid-summer. Consideration should be given to reclassify the reservoir for a Warmwater Permanent Fish Life Propagation use based on a use attainability assessment of "natural conditions" regarding ambient water temperatures.

5.5.2.1.5 Water Clarity

5.5.2.1.5.1 Secchi Transparency

Figure 5.8 displays a box plot of the Secchi depth transparencies measured along Big Bend Reservoir at the five sites BBDLK0987A, BBDLK1004DW, BBDLK1020DW, BBDLK1036DW, BBDLK1005DW, and Oahe Dam tailwaters during 2008. The Secchi depth of the Oahe Dam tailwaters was taken to be the Secchi depth measured in Oahe Reservoir at the near-dam monitoring site (i.e., OAHLK1073A). Secchi depth transparency decreased significantly in the upstream reaches of Big Bend Reservoir (Figure 5.8). This pronounced decrease in transparency is attributed to turbid runoff from the Bad River and sedimentation in the upstream reaches of the reservoir attributed to the Bad River. The "light" nature of these sediments and the shallowness of Big Bend Reservoir in its upstream reaches allows for wind action to continually resuspend deposited sediment in the water column.

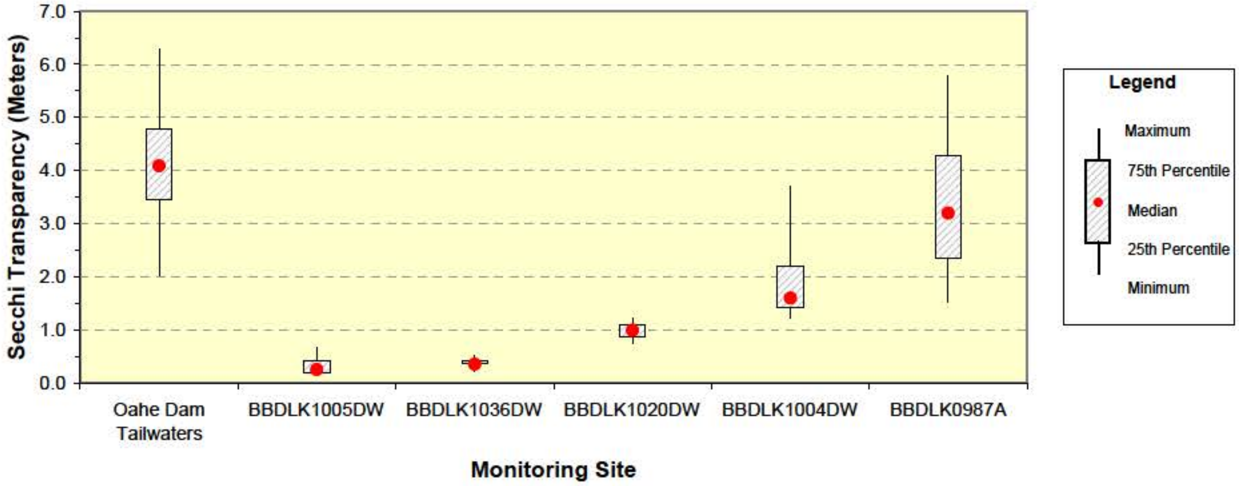

Figure 5.8. Box plot of Secchi transparencies measured in Big Bend Reservoir during 2008.

5.5.2.1.5.2 Turbidity

Monthly (i.e., June, July, August, and September) longitudinal contour plots were prepared from the depth-profile turbidity measurements taken at sites BBDLK0987A, BBDLK1004DW, BBDLK1020DW, BBDLK1036DW, BBDLK1005DW, and OAHPP1 during 2008 (Plates 210 - 213). As seen in Plates 210 through 213, turbidity levels measured in Big Bend Reservoir during 2008 varied longitudinally from the dam to the reservoir's upstream reaches; especially in June. The Bad River inflow and sedimentation delta seemingly have a pronounced impact on turbidity in the upstream reaches of Big Bend reservoir.

5.5.2.1.6 Comparison of Near-Surface and Near-Bottom Water Quality Conditions

Paired near-surface and near-bottom water quality samples collected from Big Bend Reservoir during the summer were compared. Near-surface conditions were represented by samples collected within 2-meters of the reservoir surface, and near-bottom conditions were represented by samples collected within 1-meter of the reservoir bottom. The compared samples were collected at the near-dam site BBDLK0987A during the 5-year period 2004 through 2008. During the period a total of 19 paired samples were collected monthly from June through September. Box plots were constructed to display the distribution of the paired near-surface and near-bottom measurements for the following parameters: water temperature, dissolved oxygen, oxidation-reduction potential (ORP), pH, alkalinity, total organic carbon (TOC), total Kjeldahl nitrogen (TKN), total ammonia, and total phosphorus (Plate 214). A paired two-tailed t-test was used to determine if the sampled near-surface and near-bottom conditions for the paired samples were significantly different ($\alpha = 0.05$). The sampled near-surface and near-bottom conditions were significantly different for water temperature, dissolved oxygen, ORP, and pH. Parameters that were significantly lower in the near-bottom water of Big Bend Reservoir included: water temperature ($p < 0.001$), dissolved oxygen ($p < 0.001$), and pH ($p < 0.01$). Parameters that were significantly higher in the near-bottom water included: ORP ($p < 0.05$).

5.5.2.1.7 Reservoir Trophic Status

Trophic State Index (TSI) values for Big Bend Reservoir were calculated from monitoring data collected during the 2008 (Table 5.12). The calculated TSI values indicate that the area near the dam (i.e., site BBDLK0987A) is mesotrophic, the middle reaches of the reservoir (i.e., site BBDLK1020DW)

is eutrophic, and the upstream reaches of the reservoir (i.e., site BBDLK1055DW) may be hypereutrophic. However, it is noted that the calculated average TSI value for the upstream reaches is greatly influenced by the low water clarity in this part of the reservoir. This lack of water clarity is largely attributed to suspended inorganic material delivered to the reservoir by the Bad River. Thus, the higher TSI values in the upstream reaches may not be indicative of increased algal growth associated with nutrient enrichment.

Table 5.12. Mean Trophic State Index (TSI) values calculated for Big Bend Reservoir. TSI values are based on monitoring at the identified three sites during 2008.

Monitoring Site	Mean – TSI (Secchi Depth)	Mean – TSI (Total Phos.)	Mean – TSI (Chlorophyll)	Mean – TSI (Average)
BBDLK0987A	45	50	52	49
BBDLK1020DW	61	59	59	59
BBDLK1055DW	79	62	56	66

Note: See Section 4.1.4 for discussion of TSI calculation.

5.5.2.1.8 Phytoplankton Community

Phytoplankton grab samples collected from Big Bend Reservoir at sites BBDLK0987A, BBDLK1020DW, and BBDLK1055DW during the spring and summer of the 5-year period 2004 through 2008 are summarized in Plates 215 through 217. The following seven taxonomic divisions were represented by taxa collected in the phytoplankton samples: Bacillariophyta (Diatoms), Chlorophyta (Green Algae), Chrysophyta (Golden Algae), Cryptophyta (Cryptomonad Algae), Cyanobacteria (Blue-Green Algae), Pyrrophyta (Dinoflagellate Algae), and Euglenophyta (Euglenoid Algae). The general prevalence of these taxonomic divisions in the reservoir, based on taxa occurrence, were Bacillariophyta > Chlorophyta/Cyanobacteria > Cryptophyta/Pyrrophyta > Chrysophyta > Euglenophyta. The diatoms were generally the most abundant algae based on percent composition (Plates 215 - 217). The Shannon-Weaver genera diversity indices calculated for the 31 phytoplankton samples collected at the three sites ranged from 0.16 to 2.74 and averaged 1.50 at site BBDLK0987A, 1.79 at site BBDLK1020DW, and 1.68 at site BBDLK1055DW. Dominant phytoplankton genera sampled at the three sites in 2008 (i.e., genera comprising more than 10% of the total biovolume of at least one sample collected in 2008) included the Bacillariophyta *Asterionella*, *Fragilaria, and Tablellaria*; Chlorophyta *Chlamydomonas*, *Closterium*, *Cosmarium, and Crucigenia*; Cryptophyta *Rhodomonas*; and Pyrrophyta *Ceratium*. No concentrations of the Cyanobacteria microcystin toxin above 1 ug/l were monitored at site BBDLK0987A during 2005 through 2008 (Plate 195).

5.5.2.1.9 Impairment of Designated Water Quality Beneficial Uses

Based on the State of South Dakota's impairment assessment methodology (Section 4.1.6.4), the water quality conditions monitored in Big Bend Reservoir during the 5-year period 2004 through 2008 indicate that the designated Coldwater Permanent Fish Life Propagation use is not being attained due to warm water temperatures. Consideration should be given to reclassify the reservoir for a Warmwater Permanent Fish Life Propagation use based on a use attainability assessment of "natural conditions" regarding ambient water temperatures.

5.5.2.2 Water Quality Trends (1980 through 2008)

Water quality trends over the 29-year period of 1980 through 2008 were determined for Big Bend Reservoir for Secchi depth, total phosphorus, chlorophyll *a*, and TSI (i.e., trophic status). The assessment was based on near-surface sampling of water quality conditions in the reservoir during the months of May through October at the near-dam, ambient monitoring site (i.e., site BBDLK0987A). Plate 219 displays a scatter-plot of the collected data for the four parameters, a linear regression trend line, and the significance of the trend line (i.e., $\alpha = 0.05$). For the assessment period, Big Bend Reservoir exhibited significant trends for Sechhi depth (decreasing), chlorophyll *a* (decreasing), and TSI (increasing) (Plate 2194). No significant trend was detected for total phosphorus (Plate 164). Over the 29-year period, the reservoir has generally remained in a mesotrophic to moderately eutrophic (Plate 219).

5.5.3 EXISTING WATER QUALITY CONDITIONS OF THE MISSOURI AND BAD RIVER INFLOWS TO BIG BEND RESERVOIR

5.5.3.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

The water quality conditions of the Missouri River inflow to Big Bend Reservoir is taken to be the monitored water quality conditions of the outflow from Oahe Dam. See Plate 170 for a summary of the water quality conditions monitored on the water discharged from Oahe Dam. The water quality conditions of the Bad River inflow to Big Bend Reservoir monitored at site BBDNFBADR1 during 2008 are summarized in Plate 220.

5.5.3.2 Missouri River Inflow Nutrient Flux Conditions

Nutrient flux rates for the Missouri River inflow to Big Bend Reservoir over the last 5 years were calculated based on water quality conditions monitored on water discharged through Oahe Dam (i.e. site OAHPP1) (Table 5.13). The maximum nutrient flux rates are attributed to higher flows during maximum power production at Oahe Dam.

Table 5.13. Summary of nutrient flux rates (kg/sec) calculated for the Missouri River at Oahe Dam (i.e., site OAHPP1) over the 5-year period 2004 through 2008.

Statistic	Flow (cfs)	Total Ammonia N (kg/sec)	Total Kjeldahl N (kg/sec)	Total NO_3-NO_2 N (kg/sec)	Total Phosphorus (kg/sec)	Dissolved Phosphorus (kg/sec)	Total Organic Carbon (kg/sec)
No. of Obs.	43	43	43	43	43	29	41
Mean	22,063	0.0455	0.2532	0.0024	0.0235	0.0083	1.9044
Median	20,994	0.3600	0.2211	n.d.	0.0150	0.0055	1.5781
Minimum	1,427	n.d.	n.d.	n.d.	n.d.	n.d.	0.1010
Maximum	48,097	0.3469	0.9229	0.0588	0.2451	0.0316	4.2055

n.d. = Nondetectable.
Note: Nondetect values set to 0 for flux calculations.

5.5.3.3 Mean Daily Discharge and Temperature

Mean daily discharge and water temperature of the Oahe Dam outflow was determined for the past 4 years. These are considered the water quality conditions of the Missouri River inflow to Big Bend Reservoir. Plates 221, 222, 223, and 224, respectively, plot 2005, 2006, 2007, and 2008 mean daily water temperature and flow for the Oahe Dam discharge.

5.5.4 WATER QUALITY AT THE BIG BEND DAM POWERPLANT

5.5.4.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

Plate 225 summarizes the water quality conditions that were monitored on water discharged through Big Bend Dam during the 5-year period 2004 through 2008. A review of these results found no significant water quality concerns. On a one occasion, the measured dissolved oxygen concentration was 3.8 mg/l, which is below the water quality standards dissolved oxygen criterion of 5 mg/l for the protection of warmwater permanent fish life propagation.

5.5.4.2 Temperature, Dissolved Oxygen, and Dam Discharge Time-Series Plots

Semiannual time-series plots for temperature, dissolved oxygen, and dam discharge monitored at the Big Bend powerplant during the 5-year period 2004 through 2008 were constructed. Water temperatures showed seasonal warming and cooling through each calendar year (Plates 226 - 235). Dissolved oxygen levels remained relatively high and stable during the winter, steadily declined through the spring and summer, and steadily increased during the fall (Plates 236 - 245). The lowest dissolved oxygen levels occurred during the July to August period. The higher winter, declining spring, and increasing fall dissolved oxygen concentrations are attributed to decreasing dissolved oxygen solubility with warmer water temperatures. There appeared to be some correlation between discharge rates and water temperature and dissolved oxygen concentrations measured during the summer months (Plates 226 - 245). The lower dissolved oxygen concentrations monitored in the summer may be attributed to periodic stratification and the degradation of dissolved oxygen conditions near the bottom of the reservoir. Since the inlet to the powerhouse is located at the reservoir bottom, lower flows through the dam may result in a "laminar" flow that pulls in water with degraded dissolved oxygen conditions along the bottom into the powerplant.

5.5.4.3 Comparison of Monitored Inflow and Outflow Temperatures of the Missouri River at Big Bend Reservoir

Plates 246 through 249, respectively, plot the mean daily water temperatures monitored for the Missouri River at Oahe Dam (site OAHPP1) and the Big Bend Dam powerplant (site BBDPP1) for 2005, 2006, 2007, and 2008. Inflow temperatures of the Missouri River to Big Bend Reservoir are about 4°C warmer than the outflow temperatures of Big Bend Dam during the winter (Plates 246 - 249). Outflow temperatures of the Big Bend Dam discharge are about 2°C warmer than the inflow temperatures of the Missouri River during the spring, summer, and fall (Plates 246 - 249).

5.6 FORT RANDALL

5.6.1 BACKGROUND INFORMATION

5.6.1.1 Project Overview

Fort Randall Dam is located on the Missouri River at RM 880.0 in southeastern South Dakota, 50 miles southwest of Mitchell, SD. The closing of Fort Randall Dam in 1952 resulted in the formation of Fort Randall Reservoir (Lake Francis Case). When full, the reservoir is 107 miles long, covers 102,000 acres, and has 540 miles of shoreline. Table 5.14 summarizes how the surface area, volume, mean depth, and retention time of Fort Randall Reservoir vary with pool elevations. The reservoir at the end of December 2008 was at pool elevation 1340.9 ft-msl. This is 9.1 feet below the top of the Carryover Multiple Use Zone (1350.0 ft-msl). A "low" pool level is typical for Fort Randall Reservoir at the end of December because this reservoir is drawn down each fall to provide storage space for high winter power

releases from Oahe and Big Bend. Major inflows to Fort Randall Reservoir are the Missouri River and White River. Water discharged through Fort Randall Dam for power production is withdrawn from Fort Randall Reservoir at elevation 1229 ft-msl, approximately 2 feet above the reservoir bottom.

Fort Randall Reservoir was authorized for the purposes of flood control, recreation, fish and wildlife, hydroelectric power production, water supply, water quality, navigation, and irrigation. The powerplant has eight generating units that produce an annual average 1.757 million megawatt hours of electricity, valued in excess of $28 million in revenue. Habitat for two endangered species, pallid sturgeon and interior least tern, and one threatened species, piping plover, occur within the project area. Fort Randall Reservoir is used as a water supply by the communities of Chamberlain, Dante, Geddes, Greenwood, Kimball, Lake Andes, Marty, Oacoma, Platte, Pickstown, Pukkwana, Ravinia, Reliance, Wagner, and White Lake, SD. The reservoir is an important recreational resource and a major visitor destination in South Dakota.

Table 5.14. Surface area, volume, mean depth, and retention time of Fort Randall Reservoir at different pool elevations based on 1996 survey.

Elevation (Feet-msl)	Surface Area (Acres)	Volume (Acre-Feet)	Mean Depth (Feet)*	Retention Time (Years)**
1370	98,438	4,916,698	49.9	0.270
1365	94,801	4,433,011	46.7	0.244
1360	89,808	3,971,266	44.2	0.218
1355	85,453	3,531,526	41.3	0.194
1350	76,747	3,124,368	40.7	0.172
1345	68,588	2,761,139	40.3	0.152
1340	59,783	2,439,591	40.8	0.134
1335	50,547	2,165,606	42.8	0.119
1330	45,845	1,926,136	42.0	0.106
1325	40,277	1,711,773	42.5	0.094
1320	37,911	1,517,486	40.0	0.083
1315	35,000	1,335,568	38.2	0.073
1310	33,632	1,164,645	34.6	0.064
1305	32,119	1,000,024	31.1	0.055
1300	30,297	843,949	27.9	0.046
1295	28,608	696,350	24.3	0.038
1290	26,042	559,475	21.5	0.031

Average Annual Inflow (1967 through 2007) = 18.23 Million Acre-Feet.
Average Annual Outflow: (1967 through 2007) = 17.96 Million Acre-Feet.
* Mean Depth = Volume ÷ Surface Area.
** Retention Time = Volume ÷ Average Annual Outflow.
Note: Exclusive Flood Control Zone (elev. 1375-1365 ft-msl), Annual Flood Control and Multiple Use Zone (elev. 1365-1350 ft-msl), Carryover Multiple Use Zone (1350-1320 ft-msl), and Permanent Pool Zone (elev. 1320-1227 ft-msl). All elevations are in the NGVD 29 datum.

5.6.1.2 Water Quality Standards Classification and Section 303(d) Listings

5.6.1.2.1 Fort Randall Reservoir

South Dakota has classified the Missouri River impoundments within the State as flowing streams and not reservoirs (South Dakota Administrative Rules 74:51:01:43). The State of South Dakota has designated the following water quality-dependent beneficial uses for Fort Randall Reservoir in the

State's water quality standards: recreation (i.e., immersion and limited-contact), warmwater permanent fish life propagation, domestic water supply, agricultural water supply (i.e., irrigation and stock watering), commerce and industrial waters, and fish and wildlife propagation. The State of South Dakota has not placed Fort Randall Reservoir on the State's Section 303(d) list of impaired waters and has not issued a fish consumption advisory for the reservoir.

5.6.1.2.2 Missouri River Downstream of Fort Randall Dam

South Dakota's water quality standards designate the following beneficial uses for the Missouri River downstream of Fort Randall Dam: recreation (i.e., immersion and limited-contact), warmwater permanent fish life propagation, domestic water supply, agricultural water supply (i.e., irrigation and stock watering), commerce and industrial waters, and fish and wildlife propagation. The State of South Dakota has not placed the Missouri River downstream of Fort Randall Dam on the State's Section 303(d) list of impaired waters and has not issued a fish consumption advisory for the river.

5.6.1.2.3 Ambient Water Quality Monitoring

The District has monitored water quality conditions at the Fort Randall Project since the late 1970's. Water quality monitoring locations have included sites on the reservoir and on the inflow to and outflow from the reservoir. The water quality conditions of the Big Bend Dam discharge are taken to represent the inflow water quality conditions of the Missouri River to Fort Randall Reservoir. A 3-year intensive water quality survey was completed at the Fort Randall Project in 2008, and the findings of the intensive survey are available in the separate report, "Water Quality Conditions Monitored at the Corps' Fort Randall Project in South Dakota during the 3-Year period 2006 through 2008" (USACE, 2009b). Figure 5.9 shows the location of sites at the Fort Randall Project that have been monitored for water quality during the past 5 years (i.e., 2004 through 2008). The near-dam location (i.e., site FTRLK0880A) has been continuously monitored since 1980.

5.6.2 WATER QUALITY IN FORT RANDALL RESERVOIR

5.6.2.1 <u>Existing Water Quality Conditions (2004 through 2008)</u>

5.6.2.1.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

Water quality conditions that were monitored in Fort Randall Reservoir at sites FTRLK0880A, FTRLK0892DW, FTRLK0911DW, FTRLK0924DW, FTRLK0940DW, FTRLK0955DW, and FTRLK0968DW from May through September during the 5-year period 2004 through 2008 are summarized in Plates 250 through 256. A review of these results indicated possible water quality concerns regarding dissolved oxygen and suspended solids for the support of Warmwater Permanent Fish Life Propagation. Dissolved oxygen levels in the hypolimnion degrade along the reservoir bottom as summer progresses and fall below 5.0 mg/l in July and August (Plates 250 - 253). The lowest dissolved oxygen concentration measured at the seven sites was 0.1 mg/l and occurred at site FTRLK0955DW on June 9, 2008. The chronic suspended solids criterion was exceeded in Fort Randall Reservoir in the area near the confluence of the White River (Plate 254).

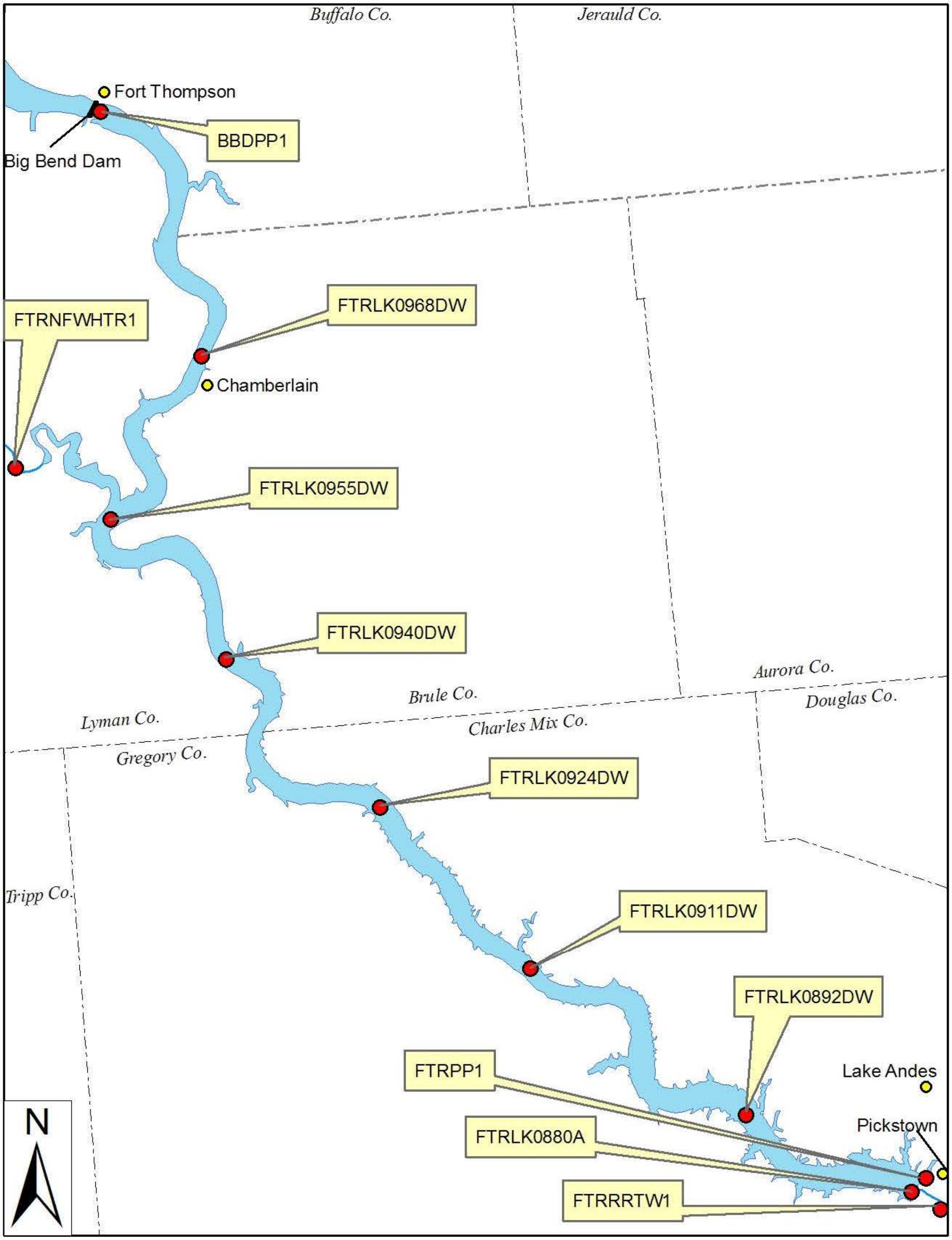

Figure 5.9. Location of sites where water quality monitoring was conducted by the District at the Fort Randall Project during the 5-year period 2004 through 2008.

5.6.2.1.2 Summer Thermal Stratification

5.6.2.1.2.1 2008 Monthly Longitudinal Temperature Contour Plots

Summer thermal stratification of Fort Randall Reservoir during 2008 is described by the monthly longitudinal temperature contour plots based on depth-profile temperature measurements taken in June, July, August, and September (Plates 257 - 260). The contour plots were constructed along the length of the reservoir. As seen in Plates 257 through 260, water temperature in Fort Randall Reservoir varies longitudinally from the dam to the reservoir's upstream reaches and vertically from the reservoir surface to the bottom. Water temperatures in the upstream reaches of the reservoir are influenced by the discharges from Big Bend Dam (RM987) and inflows from the White River (RM956). It appears that inflows from the White River tend to locally warm Fort Randall Reservoir in the spring and early-summer (Plates 257 - 259) and locally cool the reservoir in late-summer/early-fall (Plate 260). In early- and late-summer an appreciable vertical thermal gradient was present in the lacustrine, downstream region of the reservoir (Plates 258 and 259). By late summer this vertical thermal gradient had diminished greatly (Plate 260).

5.6.2.1.2.2 Near-Dam Temperature Depth-Profile Plots

Existing summer thermal stratification of Fort Randall Reservoir in the deep water area near the dam is described by the depth-profile temperature measurements taken over the 5-year period 2004 through 2008. Depth-profile temperatures measured during the summer months at site FTRLK0880A were compiled and plotted (Plate 261). The depth-profile temperature plots indicate that a moderate temperature-depth gradient occasionally occurred in the summer in the deeper area of Lake Francis Case near the dam. A significant thermocline develops at a depth of about 20 to 25 meters in mid-summer (Plates 258, 259, and 261). Thermal stratification breaks down in late summer as water column mixing is seemingly induced by reservoir drawdown, warming of the hypolimnion, and bottom withdrawals from the reservoir.

5.6.2.1.3 Summer Dissolved Oxygen Conditions

5.6.2.1.3.1 2008 Monthly Longitudinal Dissolved Oxygen Contour Plots

Dissolved oxygen contour plots were constructed along the length of Fort Randall Reservoir based on depth-profile measurements taken in June, July, August, and September of 2008 (Plates 262 - 265). During the summer of 2008, dissolved oxygen conditions in Fort Randall Reservoir varied longitudinally from the dam to the reservoir's upstream reaches and vertically from the reservoir surface to the bottom (Plates 262 - 265). Dissolved oxygen levels below 5 mg/l were monitored in June near the reservoir bottom in the area at the confluence of the White River (Plate 262). This may have been attributed to a runoff event as dissolved oxygen levels recovered to near saturation levels when monitored the following month (Plate 263). A significant area of low dissolved oxygen (i.e., <5 mg/l) occurred in the downstream area of the reservoir near the dam (Plate 264). The area of low dissolved oxygen occurred along the reservoir bottom in the hypolimnion, and dissipated in September when thermal stratification broke down and reservoir mixing occurred (Plate 265).

5.6.2.1.3.2 Near-Dam Dissolved Oxygen Depth-Profile Plots

Dissolved oxygen depth-profiles measured during the summer at site FTRLK0880A over the 5-year period 2004 through 2008 were plotted (Plate 266). Dissolved oxygen levels exhibited occasional gradients with depth. On six occasions (i.e., August 3, 2004; August 17, 2005; July 20, 2006; July 19, 2007; August 16, 2007; and August 12, 2008), hypolimnetic dissolved concentrations fell below 5.0 mg/l.

Dissolved oxygen levels below 5 mg/l occurred near the reservoir bottom from mid-July through August, when thermal stratification was maintained in Fort Randall Reservoir.

5.6.2.1.4 Water Clarity

5.6.2.1.4.1 Secchi Transparency

Figure 5.10 displays a box plot of the Secchi depth transparencies measured along Fort Randall Reservoir at the eight sites FTRLK0880A (RM880), FTRLK0892DW (RM892), FTRLK0911DW (RM911), FTRLK0924DW (RM924), FTRLK0940DW (RM940), FTRLK0955DW (RM955), FTRLK0968DW (RM968), and Big Bend Dam tailwaters during the 3-year period 2006 through 2008. The Secchi depth of the Big Bend Dam tailwaters was taken to be the Secchi depth measured in Big Bend Reservoir at the near-dam monitoring site (i.e., BBDLK0987A). The inflow of the White River to Fort Randall Reservoir was just upstream of monitoring site FTRLK0955DW. Secchi depth transparency significantly decreased from the Big Bend Dam tailwaters to the upstream reaches of Fort Randall Reservoir (Figure 5.10). The lower transparencies in the upstream reaches of the reservoir are attributed to the shallowness of the reservoir in this area and the resuspension of deposited bottom sediments with wind and wave action. Water transparency generally increased in a downstream direction from the upstream reaches of the reservoir to near the dam (Figure 5.10). However, the inflow of the White River seemingly reduced the transparency of the reservoir from levels measured upstream of the inflow. The near-surface transparency of Fort Randall Reservoir measured near the dam was significantly higher than the transparency measured in upstream reaches of the reservoir (Figure 5.10).

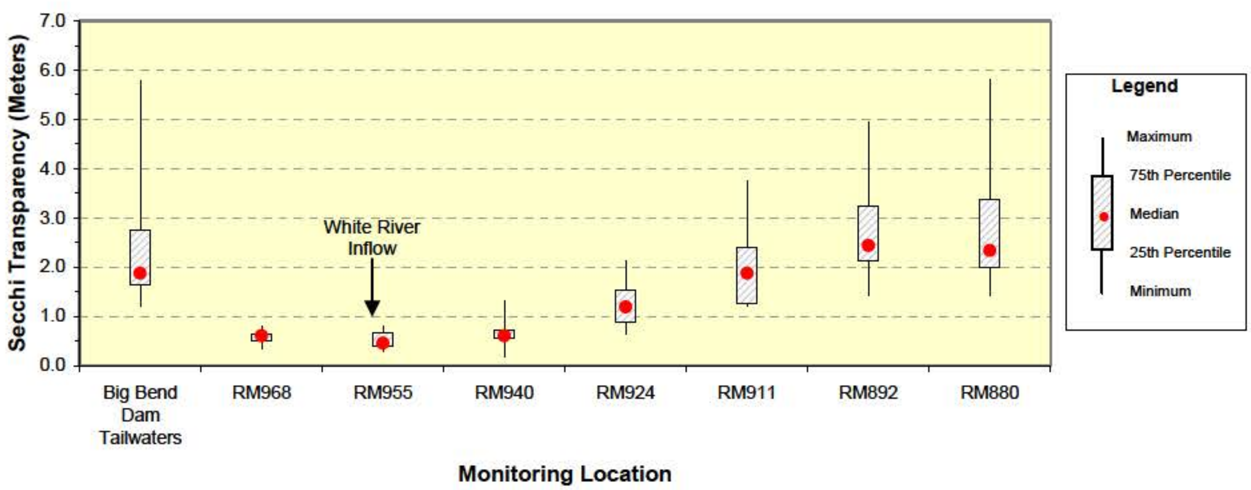

Figure 5.10. Box plot of Secchi transparencies measured along Fort Randall Reservoir during the 3-year period 2006 through 2008. (Note: monitoring sites are oriented on the x-axis in an upstream to downstream direction.)

5.6.2.1.4.2 Turbidity

Turbidity is an expression of the optical property that causes light to be scattered and absorbed rather than transmitted with no change in direction or flux level. Turbidity in water is caused by suspended and colloidal matter such as clay, silt, finely divided organic and inorganic matter, plankton, and other microscopic organisms. Monthly (i.e., June, July, August, and September) longitudinal turbidity contour plots of Fort Randall Reservoir were constructed for 2008 (Plates 267 - 270). The turbidity contour plots were developed from the turbidity depth-profiles measured at the reservoir

monitoring sites along the submerged old Missouri River channel. The contour plots show that turbidity levels in Fort Randall Reservoir vary longitudinally and vertically. The inflow of the White River near RM955 significantly influences the turbidity of Fort Randall Reservoir in the area near the inflow of the River (Plates 267 - 270). Elevated levels of turbidity attributable to the inflow of the White River were regularly seen in Fort Randall Reservoir up to 25 miles downstream from the White River inflow (Plate 270). Turbidity levels in Fort Randall Reservoir near the dam were typically quite low. Given the low chlorophyll *a* concentrations monitored in Fort Randall Reservoir (Plates 250 - 256), the variable turbidity in the reservoir is believed to be largely due to suspended inorganic material delivered by the White River; especially during runoff events.

5.6.2.1.5 Comparison of Near-Surface and Near-Bottom Water Quality Conditions

Paired near-surface and near-bottom water quality samples collected from Fort Randall Reservoir during the summer were compared. Near-surface conditions were represented by samples collected within 2-meters of the reservoir surface, and near-bottom conditions were represented by samples collected within 2-meters of the reservoir bottom. The compared samples were collected at the near-dam site FTPLK0880A during the 5-year period 2004 through 2008. During the period a total of 16 paired samples were collected monthly from June through September. Box plots were constructed to display the distribution of the paired near-surface and near-bottom measurements for the following parameters: water temperature, dissolved oxygen, oxidation-reduction potential (ORP), pH, alkalinity, total organic carbon (TOC), total Kjeldahl nitrogen (TKN), total ammonia, and total phosphorus (Plate 271). A paired two-tailed t-test was used to determine if the sampled near-surface and near-bottom conditions for the paired samples were significantly different ($\alpha = 0.05$). The sampled near-surface and near-bottom conditions were significantly different for all the assessed parameters except alkalinity, total ammonia, and total phosphorus. Parameters that were significantly lower in the near-bottom water of Fort Randall Reservoir included: water temperature ($p < 0.001$), dissolved oxygen ($p < 0.001$), and pH ($p < 0.001$). Parameters that were significantly higher in the near-bottom water included: ORP ($p < 0.01$), TOC ($p < 0.05$) and TKN ($p < 0.05$).

5.6.2.1.6 Reservoir Trophic Status

Trophic State Index (TSI) values for Fort Randall Reservoir were calculated from monitoring data collected at sites FTRLK0880A, FTRLK0991DW, FTRLK0940DW, and FTRLK0968DW during the 3-year period 2006 through 2008 (Table 5.15). The calculated TSI values indicate that the lacustrine zone of the reservoir near the dam (site FTRLK0880A) is mesotrophic, the area near site FTRLK0911DW is moderately eutrophic, and the upstream transition and riverine zones of the reservoir (sites FTRLK940DW and FTRLK0968DWDW) are eutrophic. However, it is noted that the calculated average TSI values for the transition and riverine zones are greatly influenced by the low water clarity in this part of the reservoir. This lack of water clarity is largely attributed to suspended inorganic material delivered to the reservoir by the White River. Thus, the higher TSI values in this part of the reservoir are probably not indicative of increased algal growth associated with nutrient enrichment.

Table 5.15. Mean Trophic State Index (TSI) values calculated for Fort Randall Reservoir. TSI values are based on monitoring at the identified four sites during 2006 and 2007.

Monitoring Site	Mean – TSI (Secchi Depth)	Mean – TSI (Total Phos.)	Mean – TSI (Chlorophyll)	Mean – TSI (Average)
FTRLK0880A	46	52	44	47
FTRLK0911DW	49	49	52	51
FTRLK0940DW	69	53	59	60
FTRLK0968DW	68	56	54	59

Note: See Section 4.1.4 for discussion of TSI calculation.

5.6.2.1.7 Phytoplankton Community

Phytoplankton grab samples collected from Fort Randall Reservoir at sites FTRLK0880A, FTRLK0911DW, FTRLK0940DW, and FTRLK0968DW during the spring and summer of the 5-year period 2004 through 2008 are summarized in Plates 272 through 275. The following seven taxonomic divisions were represented by taxa collected in the phytoplankton samples: Bacillariophyta (Diatoms), Chlorophyta (Green Algae), Chrysophyta (Golden Algae), Cryptophyta (Cryptomonad Algae), Cyanobacteria (Blue-Green Algae), Pyrrophyta (Dinoflagellate Algae), and Euglenophyta (Euglenoid Algae). The general prevalence of these taxonomic divisions in the reservoir, based on taxa occurrence, were Bacillariophyta > Chlorophyta > Cyanobacteria > Chrysophyta/Cryptophyta/Pyrrophyta > Euglenophyta. The diatoms were generally the most abundant algae based on percent composition (Plates 272 - 275). The Shannon-Weaver genera diversity indices calculated for the 57 phytoplankton samples collected at the four sites ranged from 0.27 to 2.86 and averaged 1.39 at site FTRLK0880A, 1.53 at site FTRLK0911DW, 1.76 at site FTRLK0940DW, and 4.53 at site FTRLK0968DW. Dominant phytoplankton genera sampled at the four sites in 2008 (i.e., genera comprising more than 10% of the total biovolume of at least one sample collected in 2008) included the Bacillariophyta *Asterionella, Aulacoseira, Fragilaria, and Tablellaria*; Chlorophyta *Chlamydomonas and Staurastrum*; Cryptophyta *Rhodomonas*; and Pyrrophyta *Ceratium* (Plate 276). The highest concentration of the Cyanobacteria microcystin toxin measured at the four sites during the 4-year-period 2005 through 2008 was 1.8 ug/l at site FTRLK0880A.

5.6.2.1.8 Impairment of Designated Water Quality Beneficial Uses

Based on the State of South Dakota's impairment assessment methodology (Section 4.1.6.4), the water quality conditions monitored in Fort Randall Reservoir during the 5-year period 2004 through 2008 did not indicate impairment of any designated water quality beneficial uses. Exceedence of the total suspended solids chronic criteria (i.e., 90 mg/l) is at the 10 percent criteria for non support (i.e., Warmwater Permanent Fish Life Propagation) in the area of the reservoir at the confluence of the White River.

5.6.2.2 <u>Water Quality Trends (1980 through 2008)</u>

Water quality trends over the period of 1980 through 2008 were determined for Fort Randall Reservoir for Secchi depth, total phosphorus, chlorophyll *a*, and TSI (i.e., trophic status). The assessment was based on near-surface sampling of water quality conditions in the reservoir during the months of May through October at the near-dam, ambient monitoring site (i.e., site FTRLK0880A). Plate 277 displays a scatter-plot of the collected data for the four parameters, a linear regression trend line, and the significance of the trend line (i.e., $\alpha = 0.05$). For the assessment period, Fort Randall Reservoir exhibited significant trends for Sechhi depth (decreasing) and chlorophyll *a* (decreasing) (Plate 277). No significant trends were detected for total phosphorus and TSI (Plate 277). Over the 29-year period, the downstream reach of Fort Randall Reservoir has generally remained in a mesotrophic state (Plate 277).

5.6.3 EXISTING WATER QUALITY CONDITIONS OF THE MISSOURI RIVER INFLOW TO FORT RANDALL RESERVOIR

5.6.3.1 <u>Statistical Summary and Comparison to Applicable Water Quality Standards Criteria</u>

The water quality conditions of the Missouri River inflow to Fort Randall Reservoir is taken to be the monitored water quality conditions of the outflow from Big Bend Dam. See Plate 225 for a summary of the water quality conditions monitored on the water discharged through Big Bend Dam.

5.6.3.2 Missouri River Inflow Nutrient Flux Conditions

Nutrient flux rates for the Missouri River inflow to Fort Randall Reservoir over the last 5 years were calculated based on water quality conditions monitored on water discharged through Big Bend Dam (i.e. site BBDPP1) (Table 5.16). The maximum nutrient flux rates are attributed to higher flows during maximum power production at Big Bend Dam.

Table 5.16. Summary of nutrient flux rates (kg/sec) calculated for the Missouri River at Big Bend Dam (i.e., site BBDPP1) over the 5-year period 2004 through 2008.

Statistic	Flow (cfs)	Total Ammonia N (kg/sec)	Total Kjeldahl N (kg/sec)	Total NO_3-NO_2 N (kg/sec)	Total Phosphorus (kg/sec)	Dissolved Phosphorus (kg/sec)	Total Organic Carbon (kg/sec)
No. of Obs.	40	40	40	40	40	25	39
Mean	27,690	0.0457	0.3465	0.0143	0.0241	0.0098	2.4717
Median	23,386	0.0198	0.2816	n.d.	0.0134	n.d.	2.1338
Minimum	3,600	n.d.	n.d.	n.d.	n.d.	n.d.	0.3160
Maximum	71,980	0.2186	1.2184	0.2662	0.1150	0.0468	6.1146

n.d. = Nondetectable.
Note: Nondetect values set to 0 for flux calculations.

5.6.3.3 Mean Daily Discharge and Temperature

Mean daily discharge and water temperature of the Big Bend Dam outflow were determined for 2005, 2006, 2007, and 2008. These are considered the water quality conditions of the Missouri River inflow to Fort Randall Reservoir. Plates 278 through 281, respectively, plot 2005, 2006, 2007, and 2008 mean daily water temperature and flow for the Big Bend Dam discharge.

5.6.4 WATER QUALITY AT THE FORT RANDALL POWERPLANT

5.6.4.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

Plate 282 summarizes the water quality conditions that were monitored on water discharged through Fort Randall Dam during the 5-year period 2004 through 2008. A review of these results indicated no major water quality concerns.

5.6.4.2 Impairment of Designated Water Quality Beneficial Uses

Based on the State of South Dakota’s impairment assessment methodology (Section 4.1.6.4), the water quality conditions monitored in Fort Randall Dam discharge during the 5-year period 2004 through 2008 did not indicate impairment of any designated water quality beneficial uses of the downstream Missouri River.

5.6.4.3 Temperature, Dissolved Oxygen, and Dam Discharge Time-Series Plots

Semiannual time series plots for temperature and dam discharge monitored at the Fort Randall powerplant during the 5-year period of 2004 through 2008 were constructed (Plates 283 - 292). Monitored water temperatures showed seasonal cooling and warming through each calendar year. Daily water temperatures remained fairly stable during the winter, early spring, and fall and exhibited considerable variability during the late spring and summer. When thermal stratification becomes

established in Fort Randall Reservoir during the late spring, the temperature of the water discharged through the dam becomes highly dependent upon the discharge rate of the dam. This indicates that the vertical extent of the withdrawal zone in the reservoir is dependent upon the discharge rate of the dam. This is believed to be a result of the design of the intake structure (i.e., bottom withdrawal) and the presence of the submerged approach channel leading to the intake structure. Water is likely drawn from an extended vertical zone in Fort Randall Reservoir year-round, but is only evident in the temperatures monitored at the powerhouse during reservoir thermal stratification during the summer. When thermal stratification breaks down in the summer, the high correlation between dam discharge and the temperature of the discharged water no longer occurs. This occurred in mid-August in 2004 (Plate 284), September 1, 2005 (Plate 286), late-July in 2006 (Plate 288), September 1, 2007 (Plate 290), and September 1, 2008 (Plate 292).

Semiannual time series plots for dissolved oxygen and dam discharge monitored at the Fort Randall powerplant during the 5-year period of 2004 through 2008 were also constructed (Plates 293 - 301). (Note: *Due to equipment failure, no dissolved oxygen measurements were recorded in 2008 after early June.)* Dissolved oxygen levels remained relatively high and stable during the winter, steadily declined through the spring and summer, and steadily increased during the fall. The lowest dissolved oxygen levels occurred during mid-summer. The higher winter, declining spring, and increasing fall dissolved oxygen concentrations are attributed to decreasing dissolved oxygen solubility with warmer water temperatures. The decreasing dissolved oxygen in the summer is attributed to ongoing degradation of dissolved oxygen in the lower hypolimnion as the summer progressed. Water is withdrawn from Fort Randall Reservoir into the dam's power tunnels approximately 2 feet above the reservoir bottom. During the summer when Fort Randall Reservoir is thermally stratified, dissolved oxygen levels degrade near the reservoir bottom. Under such conditions, low dam discharge rates pull water with low dissolved oxygen concentrations from the near-bottom region of the hypolimnion.

During the 4-year period 2004 through 2007, 2,297 hourly measurements of dissolved oxygen were recorded in August. Of these measurements, 435 (19%) were less than the 5 mg/l dissolved oxygen water quality standard for the protection of Warmwater Permanent Fish Life Propagation (Plates 294, 296, 298, and 300). The low dissolved oxygen measurements were associated with low- or no-flow discharge conditions. The no-flow conditions may be measurements of "static water" in the penstocks that is not being continuously discharged. This water is believed to have been drawn into the penstocks along the reservoir bottom as power generation was ramped down. The lowest dissolved oxygen concentration recorded was 2.0 mg/l on August 25 and 26, 2007. Seemingly, the low dissolved oxygen levels are related to oxygen degradation in the hypolimnion during late summer. During periods of lower discharge, water is drawn along the bottom of the submerged approach channel to the dam's intake tower. This is where low dissolved oxygen would occur in the hypolimnion during mid- to late summer. A potential concern that will be investigated in the future is whether the low dissolved oxygen levels monitored in the powerplant are reflective of dissolved oxygen levels occurring in the tailwaters immediately downstream of the Fort Randall Dam.

5.6.4.4 Comparison of Monitored Inflow and Outflow Temperatures of the Missouri River at Fort Randall Reservoir

Plates 302 through 305, respectively, plot the mean daily water temperatures monitored for the Missouri River at Big Bend Dam (site BBDPP1) and the Fort Randall Dam powerplants (site FTRPP1) for 2005, 2006, 2007, and 2008. Inflow temperatures of the Missouri River to Fort Randall tend to be at little warmer than the outflow temperatures of Fort Randall Dam during the spring and early summer (Plates 302 - 305). Outflow temperatures of the Fort Randall Dam discharge tend to be a little warmer than the Missouri River inflow temperatures in the late-summer and fall (Plates 302 - 305).

5.6.5 WATER QUALITY IN THE MISSOURI RIVER DOWNSTREAM OF FORT RANDALL DAM

5.6.5.1 Missouri River Reach – Fort Randall Dam to Gavins Point Reservoir

The Missouri River downstream from Fort Randall Dam (RM880) flows in a southeasterly direction for approximately 44 miles in an unchannelized river to Gavins Point Reservoir. The major tributary in this reach is the Niobrara River which enters the Missouri River from Nebraska at RM843.5. In this reach, the Missouri River meanders in a wide channel with flow restricted to generally one main channel. Only a few side channels and backwaters are present, except at the lower end of the reach in the Gavins Point Reservoir delta. The 39-mile reach of the Missouri River from Fort Randall Dam to Running Water, SD has been designated a National Recreational River under the Federal Wild and Scenic Rivers Act (WSRA). The tailwater area of Fort Randall Dam, from RM 880 to 860, has experienced up to 6 feet of riverbed degradation and channel widening during the 1953 to 1997 time period. The rate of erosion has decreased over this period. Streambank erosion since closure of the dam in 1953 has averaged about 35 acres per year. This compares to a pre-dam rate of 135 acres per year. The Missouri River has coarser bed material above RM 870 than below, indicating some armoring of the channel immediately downstream of the dam. Downstream of the tailwater area, less erosion of the bed and streambank occurs.

5.6.5.1.1 National Recreation River Designation Pursuant to the Federal Wild and Scenic Rivers Act

The 39-mile "natural-channel" reach of the Missouri River from Fort Randall Dam to the headwaters of Gavins Point Reservoir has been designated as a National Recreational River under the Federal WSRA. The National Park Service (NPS) manages the 39-mile reach pursuant to the WSRA. The justification that supported that this reach of the Missouri River be protected as a recreational river identified its outstanding remarkable recreational, fish and wildlife, aesthetic, historical, and cultural values. Under the WSRA, the U.S. Department of Interior (i.e., NPS) is mandated to administer this reach in a manner that will protect and enhance these values for the benefit and enjoyment of present and future generations.

5.6.5.1.2 State Designations and Listings Pursuant to the Federal Clean Water Act

Pursuant to the Federal Clean Water Act, the States of South Dakota and Nebraska have designated water quality-dependent beneficial uses, in their State water quality standards, for the Missouri River from of Fort Randall Dam to Gavins Point Reservoir. South Dakota has designated the following uses for this reach of the Missouri River: recreation (i.e., immersion and limited-contact), warmwater permanent fish life propagation, domestic water supply, agricultural water supply (i.e., irrigation and stock watering), commerce and industrial waters, and fish and wildlife propagation. Nebraska has designated the following uses to this reach of the Missouri River: primary contact recreation, Class I warmwater aquatic life, agricultural water supply, and aesthetics. It has designated the use of drinking water supply to the river below the confluence of the Niobrara River. Nebraska has also designated the reach between the Nebraska-South Dakota border and Gavins Point Reservoir an Outstanding State Resource Water for "Tier 3" protection under the State's water quality standard's antidegradation policy. Neither of the States has placed this reach of the Missouri River on their Section 303(d) list of impaired waters, nor has issued a fish consumption advisory for this reach of the Missouri River.

5.6.5.2 Monitored Water Quality Conditions

The District, in cooperation with the Nebraska Department of Environmental Quality, conducted fixed-station water quality monitoring at two sites along the Missouri River from Fort Randall Dam to

Gavins Point Reservoir. The locations of the two sites were Fort Randall Dam tailwaters (site FTRRRTW1) and the Missouri River near Verdel, NE (site MORRR0851) (see Figure 5.11). During the 5-year period of 2004 through 2008, water quality samples were collected monthly from October through March and Monthly to biweekly from April through September. Plates 306 and 307 summarize the water quality conditions that were monitored at the two sites. A review of these results indicated no major water quality concerns.

5.7 GAVINS POINT

5.7.1 BACKGROUND INFORMATION

5.7.1.1 Project Overview

Gavins Point Dam is located on the Missouri River at RM 811.1 on the South Dakota-Nebraska border in southeast South Dakota and northeast Nebraska, 4 miles west of Yankton, SD. The closing of Gavins Point Dam in 1955 resulted in the formation of Gavins Point Reservoir (Lewis and Clark Lake). The reservoir is 25 miles long, covers 31,000 acres, and has 90 miles of shoreline when full. Table 5.17 summarizes how the surface area, volume, mean depth, and retention time of Gavins Point Reservoir vary with pool elevations. Gavins Point Reservoir is normally regulated near 1206.0 ft-msl in the spring and early summer with variations day to day due to rainfall runoff. The reservoir level is then increased to elevation 1207.5 ft-msl following the least tern and piping plover nesting season for reservoir recreation enhancement. Major inflows to Gavins Point Reservoir are the Missouri River and Niobrara River. Water discharged through Gavins Point Dam for power production is withdrawn from the bottom of Gavins Point Reservoir at an invert elevation of 1139.5 ft-msl.

Table 5.17. Surface area, volume, mean depth, and retention time of Gavins Point Reservoir at different pool elevations based on 2007 survey.

Elevation (Feet-msl)	Surface Area (Acres)	Volume (Acre-Feet)	Mean Depth (Feet)*	Retention Time (Years)**
1210	29,956	450,070	15.0	0.02292
1205	23,029	318,732	13.8	0.01623
1200	18,819	215,126	11.4	0.01095
1195	14,278	132,308	9.3	0.00674
1190	9,921	71,711	7.2	0.00365
1185	5,202	35,027	6.7	0.00178
1180	3,393	14,543	4.3	0.00074
1175	1,067	3,855	3.6	0.00020
1170	371	728	2.0	0.00004

Average Annual Inflow (1967 through 2008) = 19.74 Million Acre-Feet.
Average Annual Outflow: (1967 through 2008) = 19.64 Million Acre-Feet.
* Mean Depth = Volume ÷ Surface Area.
** Retention Time = Volume ÷ Average Annual Outflow.
Note: Exclusive Flood Control Zone (elev. 1210-1208 ft-msl), Annual Flood Control and Multiple Use Zone (elev. 1208-1204.5 ft-msl), Carryover Multiple Use Zone (none), and Permanent Pool Zone (elev. 1204.5-1160 ft-msl). All elevations are in the NGVD 29 datum.

Gavins Point was authorized for the proposes of flood control, recreation, fish and wildlife, hydroelectric power production, water supply, water quality, navigation, and irrigation. The powerplant has three generating units that produce an annual average 0.728 million megawatt hours of electricity, valued in excess of $12 million in revenue. Habitat for two endangered species, pallid sturgeon and interior least tern, and one threatened species, piping plover, occur within the project area. Gavins Point Reservoir is a source water supply (drinking water) for the Cedar Knox and Bon Homme-Yankton Rural

Water Districts. Gavins Point is an important recreational resource and a major visitor destination in South Dakota and Nebraska.

5.7.1.2 Water Quality Standards Classifications and Section 303(d) Listings

5.7.1.2.1 Gavins Point Reservoir

Pursuant to the Federal Clean Water Act, the State of South Dakota has designated the following water quality-dependent beneficial uses for Gavins Point Reservoir: recreation (i.e., immersion and limited-contact), warmwater permanent fish life propagation, domestic water supply, agricultural water supply (i.e., irrigation and stock watering), commerce and industrial waters, and fish and wildlife propagation. The State of Nebraska has designated the following beneficial uses to Gavins Point Reservoir: primary contact recreation, Class I warmwater aquatic life, drinking water supply, agricultural water supply, industrial water supply, and aesthetics. The uses designated by the States of South Dakota and Nebraska to Gavins Point Reservoir are consistent with each other. Neither of the two States has placed Gavins Point Reservoir on the State's Section 303(d) list of impaired waters, or has issued fish consumption advisories for the reservoir.

5.7.1.2.2 Missouri River Downstream of Gavins Point Dam

See Section 6 for a discussion of the Lower Missouri River downstream of Gavins Point Dam.

5.7.1.3 Ambient Water Quality Monitoring

The District has monitored water quality conditions at the Gavins Point Project since the late 1970's. Water quality monitoring locations have included sites on the reservoir and on the inflow to and outflow from the reservoir. A 3-year intensive water quality survey scheduled for 2008 through 2010 is currently underway at the Gavins Point Project. An investigative study to evaluate the water quality impacts of constructing emergent sandbar habitat (ESH) in the headwaters of Gavins Point Reservoir was conducted in 2008 and the findings of that study are available in the separate report, "Creation of Emergent Sandbar Habitat (ESH) in the Headwaters of Lewis and Clark Lake and the Impacts on Water Quality" (USACE, 2009c). Figure 5.11 shows the location of sites at the Gavins Point Project that have been monitored by the District for water quality during the 5-year period 2004 through 2008. The near-dam location (i.e., site GPTLK0811A) has been continuously monitored since 1980.

5.7.2 WATER QUALITY IN GAVINS POINT RESERVOIR

5.7.2.1 Existing Water Quality Conditions (2004 through 2008)

5.7.2.1.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

Water quality conditions that were monitored in Gavins Point Reservoir at sites GTPLK0811A, GTPLK0815DW, GTPLK0819DW, GTPLK0822DW, and GTPLK0825DW from May through September during the 5-year period 2004 through 2008 are summarized in Plates 308 through 312. A review of these results indicated possible water quality concerns regarding dissolved oxygen, nutrients (i.e., total nitrogen and phosphorus), and chlorophyll *a*. Based on the criteria for the protection of warmwater aquatic life, 8 percent of the dissolved oxygen measurements taken at the monitoring site near Gavins Point Dam (i.e., GPTLK0811A) did not meet the dissolved oxygen criterion of 5 mg/l. All but one of the dissolved oxygen measurements less than the criterion occurred in a defined hypolimnetic zone where 56 percent dissolved oxygen measurements were less than 5 mg/l. The Nebraska nutrient criteria for chlorophyll *a*, total nitrogen, and total phosphorus applicable to Gavins Point Reservoir, a classified R9 reservoir, were regularly exceeded throughout the reservoir (Plates 308 - 312).

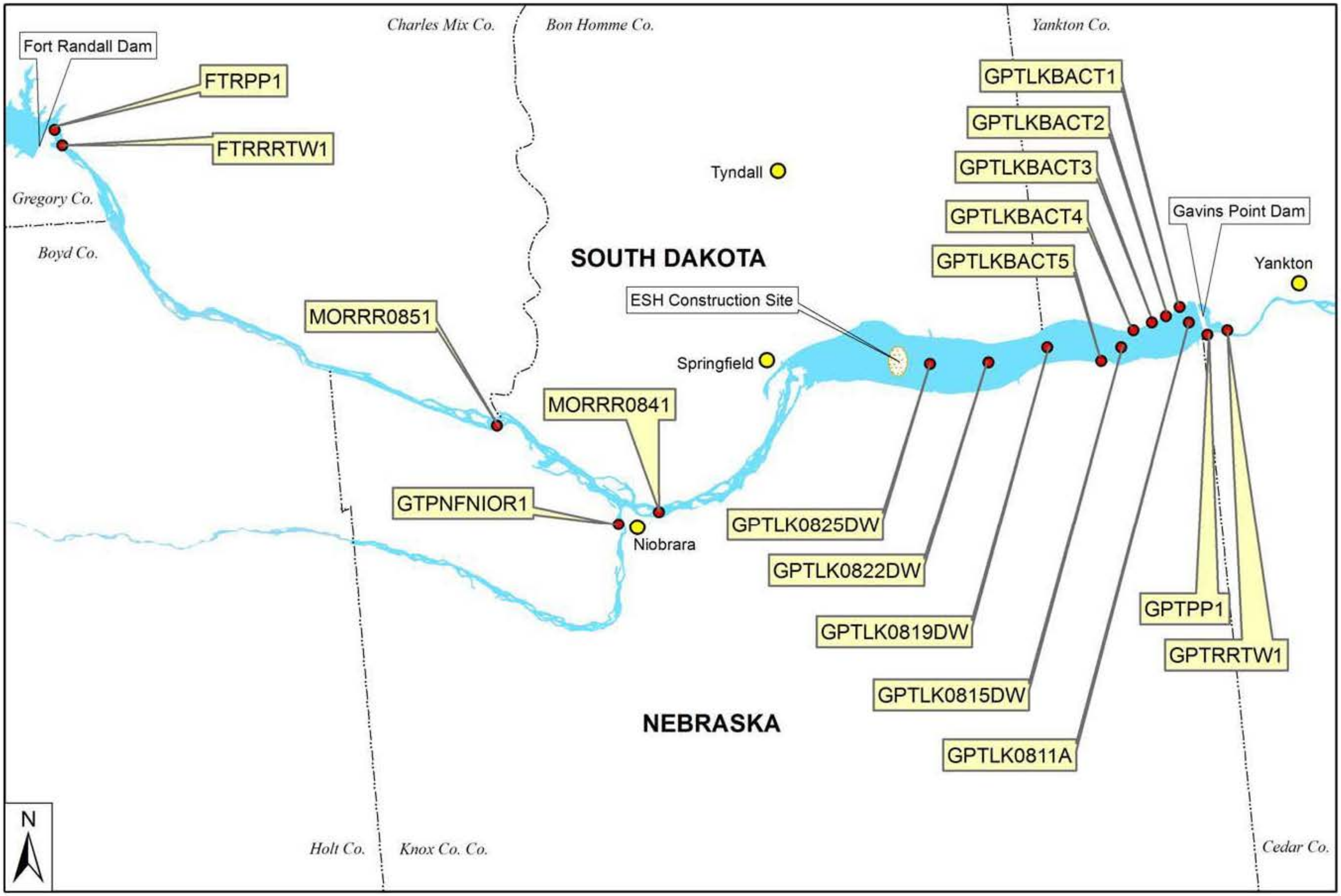

Figure 5.11. Location of sites where water quality monitoring was conducted by the District at the Gavins Point Project during the period 2004 through 2008.

5.7.2.1.2 Summer Thermal Stratification

5.7.2.1.2.1 2008 Monthly Longitudinal Temperature Contour Plots

Summer thermal stratification of Gavins Point Reservoir during 2008 is described by the monthly longitudinal temperature contour plots based on depth-profile temperature measurements taken in June, July, August, and September (Plates 313 - 316). The contour plots were constructed along the length of the reservoir. As seen in Plates 313 through 316, water temperature in Gavins Point Reservoir varies longitudinally from the dam to the reservoir's upstream reaches and vertically from the reservoir surface to the bottom. Although some summer thermal stratification of Gavins Point Reservoir can occur, the relative shallowness, short retention time, and bottom withdrawal of the reservoir seemingly inhibit the formation of a strong thermocline and long-lasting stratification during the summer. Since Gavins Point Reservoir ices over in the winter and exhibits minor thermal stratification in the summer it appears to fit the definition of a discontinuous cold polymictic lake (Wetzel, 2001). Wetzel (2001) identifies lakes as discontinuous cold polymictic if they are ice-covered part of the year and ice-free above 4°C during the warm season, and exhibit thermal stratification during the warm period for periods of several days to weeks but with irregular interruption by mixing.

5.7.2.1.2.2 Near-Dam Temperature Depth-Profile Plots

Existing summer thermal stratification of Gavins Point Reservoir at the deep water area near the dam is described by the depth-profile temperature plots measured over the 5-year period 2004 through 2008. Depth-profile temperature plots measured during the summer months were compiled (Plate 317). Minor temperature-depth gradients occasionally occur in Gavins Point Reservoir in the near-dam area during the summer (Plate 317).

5.7.2.1.3 Summer Dissolved Oxygen Conditions

5.7.2.1.3.1 2008 Monthly Longitudinal Dissolved Oxygen Contour Plots

Dissolved oxygen longitudinal contour plots were constructed along the length of Gavins Point Reservoir based on depth-profile measurements taken in June, July, August, and September of 2008 (Plates 318 - 321). During the summer of 2008, dissolved oxygen conditions in Gavins Point Reservoir varied longitudinally from the dam to the reservoir's upstream reaches and vertically from the reservoir surface to the bottom (Plates 206 - 209). Dissolved oxygen levels below 5 mg/l first appeared at the reservoir bottom near the dam in August (Plate 320). Dissolved oxygen levels recovered to near saturation levels throughout Gavins Point Reservoir by mid-September (Plate 321). There appears to have been enough thermal stratification in Gavins Point Reservoir during the summer of 2008 to allow for the degradation of dissolved oxygen levels in a small area near the dam.

5.7.2.1.3.2 Near-Dam Dissolved Oxygen Depth-Profile Plots

Existing summer dissolved oxygen conditions in Gavins Point Reservoir at the deep-water area near the dam are described by the depth-profile dissolved oxygen plots measured over the 5-year period 2004 through 2008. Depth-profile dissolved oxygen plots measured during the summer months at site GPTLK0811A were compiled (Plate 322). Dissolved oxygen levels below 5 mg/l regularly occurred near the bottom of the reservoir, and levels near the reservoir bottom approached 2 to 3 mg/l on four occasions.

5.7.2.1.4 Water Clarity

5.7.2.1.4.1 Secchi Transparency

Figure 5.12 displays a box plot of the Secchi depth transparencies measured along Gavins Point Reservoir at the five sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW during 2008. Secchi depth transparency increased in a downstream direction from the upper reaches of the reservoir to near the dam (Figure 5.12). This is attributed to suspended sediment in the inflowing Niobrara and Missouri Rivers settling out in the reservoir as current velocities slow. The surface waters near Gavins Point Dam are significantly clearer than the upstream regions of the reservoir.

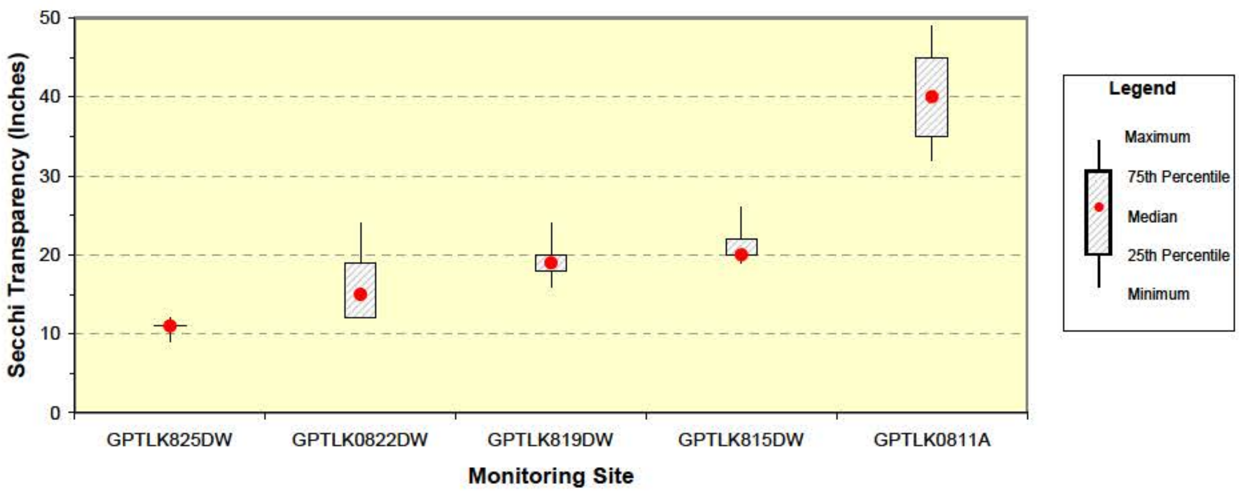

Figure 5.12. Box plot of Secchi transparencies measured in Gavins Point Reservoir during 2008.

5.7.2.1.4.2 Turbidity

Monthly (i.e., June, July, August, and September) longitudinal contour plots were prepared from the depth-profile turbidity measurements taken at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW during 2008 (Plates 323 - 326). As seen in Plates 323 through 326, turbidity levels measured in Gavins Point Reservoir during 2008 varied longitudinally from the dam to the reservoir's upstream reaches; especially in June. This is attributed to the turbid conditions of the inflowing Missouri River which is impacted by the inflow of the Niobrara River 16 miles upstream of Gavins Point Reservoir. It also appears that turbidity plumes may move through Gavins Point Reservoir as interflows; especially along the bottom during the spring runoff period.

5.7.2.1.5 Comparison of Near-Surface and Near-Bottom Water Quality Conditions

Paired near-surface and near-bottom water quality samples collected from Gavins Point Reservoir during the summer were compared. Near-surface conditions were represented by samples collected within 1-meter of the reservoir surface, and near-bottom conditions were represented by samples collected within 1-meter of the reservoir bottom. The compared samples were collected at the near-dam site GPTLK0811A during the 5-year period 2004 through 2008. During the period a total of 19 paired samples were collected monthly from June through September. Box plots were constructed to display the distribution of the paired near-surface and near-bottom measurements for the following parameters: water temperature, dissolved oxygen, oxidation-reduction potential (ORP), pH, alkalinity, total organic carbon (TOC), total Kjeldahl nitrogen (TKN), total ammonia, and total phosphorus (Plate 327). A paired two-

tailed t-test was used to determine if the sampled near-surface and near-bottom conditions for the paired samples were significantly different ($\alpha = 0.05$). The sampled near-surface and near-bottom conditions were significantly different for water temperature, dissolved oxygen, pH, and total ammonia. Parameters that were significantly lower in the near-bottom water of Gavins Point Reservoir included: water temperature ($p < 0.001$), dissolved oxygen ($p < 0.001$), and pH ($p < 0.001$). Parameters that were significantly higher in the near-bottom water included: total ammonia ($p < 0.05$).

5.7.2.1.6 Reservoir Trophic Status

Trophic State Index (TSI) values for Gavins Point Reservoir were calculated from monitoring data collected during the 2008 (Table 5.18). The calculated TSI values indicate that the area near the dam (i.e., site GPTLK0811A) is eutrophic, the middle and upper reaches of the reservoir (i.e., sites GPTLK0819DW and GTPLK0825DW) are hypereutrophic.

Table 5.18. Mean Trophic State Index (TSI) values calculated for Gavins Point Reservoir. TSI values are based on monitoring at the identified three sites during 2008.

Monitoring Site	Mean – TSI (Secchi Depth)	Mean – TSI (Total Phos.)	Mean – TSI (Chlorophyll)	Mean – TSI (Average)
GPTLK0811A	60	57	69	62
GPTLK0819DW	70	62	71	68
GPTLK0825DW	79	64	70	71

Note: See Section 4.1.4 for discussion of TSI calculation.

5.7.2.1.7 Phytoplankton Community

Phytoplankton grab samples collected from Gavins Point Reservoir at sites GPTLK0811A, GPTLK0819DW, and GPTLK0825DW during the spring and summer of the 5-year period 2004 through 2008 are summarized in Plates 328 through 330. The following seven taxonomic divisions were represented by taxa collected in the phytoplankton samples: Bacillariophyta (Diatoms), Chlorophyta (Green Algae), Chrysophyta (Golden Algae), Cryptophyta (Cryptomonad Algae), Cyanobacteria (Blue-Green Algae), Pyrrophyta (Dinoflagellate Algae), and Euglenophyta (Euglenoid Algae). The general prevalence of these taxonomic divisions in the reservoir, based on taxa occurrence, were Bacillariophyta > Chlorophyta > Cyanobacteria/Cryptophyta/Pyrrophyta > Chrysophyta/Euglenophyta. The diatoms were generally the most abundant algae based on percent composition (Plates 328 - 330). The Shannon-Weaver genera diversity indices calculated for the 31 phytoplankton samples collected at the three sites ranged from 0.68 to 2.52 and averaged 1.63 at site GPTLK0811A, 1.77 at site GPTLK0819DW, and 1.93 at site GPTLK0825DW. Dominant phytoplankton genera sampled at the three sites in 2008 (i.e., genera comprising more than 10% of the total biovolume of at least one sample collected in 2008) included the Bacillariophyta *Asterionella*, *Aulacoseira, Fragilaria, Stephanodiscus, and Synedra*; and Cryptophyta *Rhodomonas*. The Cyanobacteria microcystin toxin was detected at a level of 14 ug/l at site GPTLK0811A in 2008 (Plate 308).

5.7.2.1.8 Bacteria Monitoring at Swimming Beaches on Gavins Point Reservoir

During the 5-year period 2004 through 2008, bacteria samples were collected weekly from May through September at five swimming beaches located on Gavins Point Reservoir. The five swimming beaches where the bacteria samples were collected were: Weigand Recreation Area (site GPTLKBACT5), Gavins Point Recreation Area (site GPTLKBACT4), Lewis and Clark Recreation Area – Midway West Beach (site GPTLKBACT3) and Midway East Beach (GPTLKBACT2), and the Marina Sailing Boat Area (site GPTLKBACT1) (Figure 5.11). Table 5.19 summarizes the results of the bacteria sampling. The geometric means were calculated as running geometric means for five consecutive weekly bacteria samples and nondetects were set to 1. The bacteria sampling results were compared to following bacteria criteria for support of "full-body contact" recreation:

Fecal Coliform:
Bacteria of the fecal coliform group should not exceed a geometric mean of 200/100ml, nor equal or exceed 400/100ml, in more than 10% of the samples. These criteria are based on a minimum of five samples taken within a 30-day period.

E. coli:
E. coli bacteria should not exceed a geometric mean of 126/100ml. For increased confidence of the criteria, the geometric mean should be based on a minimum of five samples taken within a 30-day period. Single sample maximum allowable density for designated bathing beaches is 235/100ml.

Based on these criteria and Nebraska's impairment assessment methodology (Section 4.1.6.2), "full-body contact" recreation was fully supported at the five sampled swimming beaches on Gavins Point Reservoir during the May through September recreational season during the 5-year period 2004 through 2008. It is noted that 7 percent of calculated geomeans at site GPTLKBACT5 (Weigand Recreation Area) exceeded the geometric mean criteria (Table 5.19).

5.7.2.1.9 Impairment of Designated Water Quality Beneficial Uses

Based on the State of Nebraska's impairment assessment methodology (Section 4.1.6.2), the water quality conditions monitored in Gavins Point Reservoir (i.e., chlorophyll *a*, total nitrogen, and total phosphorus) during the 5-year period 2004 through 2008 indicate impairment of aesthetics due to nutrients. It is also noted that the estimated loss of 23.4 percent of the multi-purpose pool volume of Gavins Point Reservoir (Table 5.1) is approaching Nebraska's impairment identification criteria of 25 percent volume loss.

5.7.2.2 Water Quality Trends (1980 through 2008)

Water quality trends over the period of 1980 through 2008 were determined for Gavins Point Reservoir for Secchi depth, total phosphorus, chlorophyll *a*, and TSI (i.e., trophic status). The assessment was based on near-surface sampling of water quality conditions in the reservoir during the months of May through October at the near-dam monitoring site (i.e., site GPTLK0811A). Plate 332 displays a scatter-plot of the collected data for the four parameters, a linear regression trend line, and the significance of the trend line (i.e., $\alpha = 0.05$). For the assessment period, Gavins Point Reservoir exhibited significant trends for Sechhi depth (decreasing) and TSI (increasing) (Plate 332). No significant trends were detected for total phosphorus and chlorophyll *a* (Plate 332). Over the 29-year period, the near-dam area of the reservoir has generally remained in a eutrophic state (Plate 332).

Table 5.19. Summary of weekly (May through September) bacteria sampling conducted at five swimming beaches on Gavins Point Reservoir over the 5-year period 2004 through 2008.

	Weigand Recreation Area (GPTLKBACT5)	Gavins Point Recreation Area (GPTLKBACT4)	Lewis & Clark Rec. Area Midway West (GPTLKBACT3)	Lewis & Clark Rec. Area Midway East (GPTLKBACT2)	Marina Sailing Boat Area (GPTLKBACT1)
Fecal Coliform Bacteria:					
Number of Samples	106	107	107	106	107
Mean	261	48	33	46	35
Median	29	16	10	10	6
Minimum	n.d.	n.d.	n.d.	n.d.	n.d.
Maximum	7,500	700	640	990	520
Percent of samples exceeding 400/100ml	8%	3%	1%	1%	1%
• **Geometric Mean**					
Number of Geomeans	87	87	87	87	87
Average	54	18	11	14	9
Median	29	14	10	9	7
Minimum	3	2	3	n.d.	2
Maximum	682	66	69	67	39
Number of Geomeans exceeding 200/100ml	7%	0%	0%	0%	0%
E. coli **Bacteria**					
Number of Samples	106	107	107	107	107
Mean	171	35	27	31	24
Median	16	10	6	4	4
Minimum	n.d.	n.d.	n.d.	n.d.	n.d.
Maximum	5,200	450	387	960	340
Percent of samples exceeding 235/100ml	11%	3%	2%	2%	3%
• **Geomean**					
Number of Geomeans	87	87	87	87	87
Average	40	12	8	8	6
Median	16	8	7	6	5
Minimum	2	2	n.d.	n.d.	n.d.
Maximum	595	54	26	26	21
Number of Geomeans exceeding 126/100ml	7%	0%	0%	0%	0%

n.d. = Not detected.
Note: Not detected values set to 1 to calculate mean and geometric mean.

5.7.2.3 Creation of Emergent Sandbar Habitat (ESH) in the Headwaters of Gavins Point Reservoir and the Impacts on Water Quality

The U.S. Fish and Wildlife Service (USFWS) issued a Biological Opinion (BiOp) with recommendations for the U.S. Army Corps of Engineers' (Corps) operations of the Missouri River Mainstem System for protection and enhancement of threatened and endangered species. The BiOp found that the Corps' operations on the Missouri River were not likely to jeopardize the endangered interior least tern *(Sterna antillarum)* and threatened piping plover *(Charadrius melodus)* populations if

the Reasonable and Prudent Alternative (RPA) set forth in the BiOp was implemented. The RPA includes recommendations for the mechanical creation and maintenance of Emergent Sandbar Habitat (ESH) as nesting habitat for these two species in terms of habitat acres per river mile. In accordance with the BiOp, the Corps is conducting ongoing efforts to create and/or reclaim a sufficient amount of ESH to stabilize, and eventually recover, interior least tern and piping plover populations along the Missouri River. The Missouri River reach from Gavins Point Dam upstream to the confluence of the Niobrara River, which includes Gavins Point Reservoir, has been identified as a priority reach for both the interior least tern and piping plover. A project to create ESH in the upper reaches of Gavins Point Reservoir was implemented by the Corps during the period September 2006 to November 2008. Hydraulic dredging was used to construct two ESH complexes. The dredged material for building the sandbars was obtained from the "delta" of deposited material at the inflow of the Missouri River to Gavins Point Reservoir.

Gavins Point Reservoir is utilized for source water by two rural water districts that provide public drinking water; Cedar Knox Rural Water District (CKRWD) and the Bon Homme-Yankton Rural Water District (BYRWD). The City of Yankton draws source water for drinking water use from the Missouri River approximately 5 miles downstream of Gavins Point Dam. Pursuant to the Federal Safe Drinking Water Act, both rural water districts and the City of Yankton monitor their source and treated drinking water for compliance with federal drinking water standards. This monitoring includes testing for trihalomethanes (THMs) and quarterly reporting of the results to the appropriate State authorities. The current MCL (maximum contaminant level) for total THMs is 80 μg/l. When testing indicates the MCL for total THMs is exceeded, the water suppliers must notify their users, as well as increase the frequency of testing, numbers of tests, and data reporting. The water suppliers expressed concerns to the Corps that the creation of the ESH in Gavins Point Reservoir degraded water quality to the degree that it impacted the quality of their treated drinking water. Specifically, there was concern that the dredging and sandbar construction increased the level of organic matter (THM precursors) in the reservoir, and this lead to the water suppliers exceeding water quality standards in their treated drinking water for THMs.

THMs include the compounds trichloromethane (chloroform), bromodichloromethane, dibromochloromethane, and tribromomethane (bromoform). THMs are formed when free chlorine reacts with THM precursors, most of which occur naturally. THM formation in treated drinking water occurs when source water containing THM precursors is chlorinated during treatment. THMs do not occur naturally, only when the source water is treated with disinfectants such as chlorine. The organic matter that supplies the carbon compounds that serve as THM precursors in surface waters is derived from allochthonous and autochthonous material. Allochthonous organic matter in watersheds is leached from soils or decaying vegetation and transported to surface waters. Autochthonous organic matter is produced through algal, macrophyte, and bacterial production in surface waters.

THMs commonly occur in the treated drinking water provided by the CKRWD, BYRWD, and the City of Yankton. Quarterly THM levels historically reported by the three treatment facilities indicate a strong seasonal trend with lower levels occurring in the winter and higher levels in the spring and summer. Treatment processes and retention time in the distribution system seemingly have a significant impact on the THM levels occurring at the treatment facilities.

The historical data from BYRWD indicates THM levels are consistently less than half of the 80 μg/l THM MCL standard. The small range of values indicates the treated water is not prone to extreme THM values, and reflects an ability of the BYRWD to effectively manage their water treatment process given the quality of the source water. THM concentrations in the BYRWD treated water were very low before and after ESH construction, so any increase in THM precursor levels in Gavins Point Reservoir that may have occurred from ESH construction or other seasonal sources were manageable with no non-compliance occurrences observed in the quarterly data. The quarterly data indicate the ESH construction

in the upper reaches of Gavins Point Reservoir did not have an appreciable impact on the THM levels measured in BYRWD's treated water.

The reported THM levels at Yankton are notably higher than the levels reported for BYRWD. The THM levels at Yankton indicate the treatment facility has a greater vulnerability to high THM values and a greater risk for THM non-compliance events. The treatment process may have a major impact on the occurrence of THMs and non-compliance events at Yankton. The occurrence of high THM levels in Yankton's treated water do not appear to be correlated with the dredging that occurred to construct the ESH in the upper reaches of Gavins Point Reservoir. The level of THM precursors present in the Missouri River at the Yankton water intake appear to rise with the increase in organic matter attributable to spring and summer runoff and algal production in Gavins Point Reservoir.

The reported THM levels at CKRWD were also notably higher than the levels reported for BYRWD. The THM levels at CYRWD also indicate the treatment facility has a greater vulnerability to high THM values and a greater risk for THM non-compliance events. The treatment process may also have a major impact on the occurrence of THMs and non-compliance events at CKRWD. It is not clear as to whether the ESH dredging in the upper reaches of Gavins Point Reservoir had a significant impact on the quarterly THM levels reported for CKRWD. THM levels reported in 2006 and 2007, when dredging occurred, do not indicate a noticeable impact as all quarterly results were within the historical range of normal seasonal variability. Quarterly reporting for 2008 indicated THM level greater than the historic maximum in the 4^{th} quarter. This was during the period that dredging was completed on ESH complex 2.

Additional targeted water quality monitoring of treated water in the CKRWD distribution system during 2008 showed a strong seasonal trend in THM levels (i.e., low in early spring and early fall and high in the summer). THM levels in the CKRRWD distribution system were directly related to the distance from the treatment plant (i.e., locations the farthest away had the highest THM levels). Monitored THM levels associated with before and during ESH dredging periods did not indicate any impact; monitored THM levels were lower during ESH dredging.

Ambient water quality conditions monitored in Gavins Point Reservoir during 2008 were similar to conditions monitored in the past. Gavins Point Reservoir is in a eutrophic condition and experiences higher levels of algal growth during the summer. Targeted water quality monitoring was conducted in 2008 to evaluate the impact of the dredging to complete construction of ESH complex 2. Water quality monitoring of Gavins Point Reservoir was conducted immediately before and during dredging. The water quality monitoring included the parameter THM Formation Potential (THM-FP) which is a measure of the potential for THMs to form in water when under the influence of direct chlorination. Monitored levels of THM-FP (i.e., THM precursors) in Gavins Point Reservoir exhibited seasonality ("i.e., low levels in spring and fall and higher levels in the summer). This indicates that seasonal runoff and algal production (lacustrine and riverine) may be a primary source of THM precursors in Gavins Point Reservoir. THM-FP levels measured in Gavins Point Reservoir were appreciably lower than levels measured in eutrophic reservoirs in New York and Kentucky (Bukaveckas et.al., 2007 and Stepczuk et.al., 1998). Monitoring conducted immediately before and during the dredging to complete ESH complex 2 did not detect any significant impact of the dredging on the water quality of Gavins Point Reservoir. Monitored levels of THM-FP in the reservoir were lower during ESH dredging when compared to levels monitored immediately before dredging.

A more in-depth discussion of the impacts that the creation of ESH in the headwaters of Gavins Point Reservoir had on water quality is contained in the Water Quality Office Report, "Creation of Emergent Sandbar Habitat (ESH) in the Headwaters of Gavins Point Reservoir and the Impacts on Water Quality" (USACE, 2009c).

5.7.3 EXISTING WATER QUALITY CONDITIONS OF THE MISSOURI AND NIOBRARA RIVER INFLOWS TO GAVINS POINT RESERVOIR

5.7.3.1 Missouri River above the Confluence of the Niobrara River

5.7.3.1.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

The water quality conditions of the Missouri River above the confluence of the Niobrara River are defined by the water quality conditions monitored in the outflow from Fort Randall Dam (site FTRPP1), in the Fort Randall Dam tailwaters (site FTRRRTW1), and in the Missouri River near Verdel, NE (site MORRR0851). Plates 282, 306, and 307, respectively, summarize water quality conditions monitored at these three sites over the 5-year period 2004 through 2008.

5.7.3.1.2 Nutrient Flux Conditions

The nutrient flux rates of the Missouri River above the confluence of the Niobrara River, over the 5-year period 2004 through 2008, were calculated from water quality conditions monitored in the Missouri River near Verdel, NE (i.e., site MORRR0851) (Table 5.20). The maximum nutrient flux rates are attributed to higher flows during maximum power production at Fort Randall Dam.

Table 5.20. Summary of nutrient flux rates (kg/sec) calculated for the Missouri River near Verdel, NE (i.e., site MORRR0851) over the 5-year period 2004 through 2008.

Statistic	Flow (cfs)	Total Ammonia N (kg/sec)	Total Kjeldahl N (kg/sec)	Total NO_3-NO_2 N (kg/sec)	Total Phosphorus (kg/sec)	Total Organic Carbon (kg/sec)
No. of Obs.	77	77	77	77	76	75
Mean	22,202	0.0608	0.2739	0.0098	0.0262	3.6750
Median	22,131	0.0262	0.2122	n.d.	0.0173	3.3018
Minimum	3,012	n.d.	n.d.	n.d.	n.d.	1.7379
Maximum	41,299	0.3742	1.0432	0.1543	0.2315	14.1913

n.d. = Nondetectable.
Note: Non-detect values set to 0 for flux calculations.

5.7.3.1.3 Mean Daily Discharge and Temperature

Mean daily discharge and water temperature of the Fort Randall Dam outflow were determined for 2005, 2006, 2007, and 2008. These are considered the water quality conditions of the Missouri River above the confluence of the Niobrara River. Plates 333, 334, 335 and 336, respectively, plot 2005, 2006, 2007, and 2008 mean daily water temperature and flow for the Fort Randall Dam discharge.

5.7.3.2 Niobrara River

5.7.3.2.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

The water quality conditions that were monitored in the Niobrara River at site GPTNFNIOR1 (Figure 5.11) are summarized in Plate 337. A review of these results indicated no significant water quality concerns. The high levels of total iron and manganese are considered natural background conditions.

5.7.3.2.2 Nutrient Flux Conditions

Nutrient flux rates of the Niobrara River, near the river's confluence with the Missouri River, were calculated from water quality conditions monitored during 2008 at site GPTNFNIOBR1 (Table 5.21). The maximum nutrient flux rates are attributed to greater nonpoint-source nutrient loadings associated with runoff conditions.

Table 5.21. Summary of nutrient flux rates (kg/sec) calculated for the Niobrara River near Verdel, NE (i.e., site GPTNFNIOBR1) for 2008.

Statistic	Flow (cfs)	Total Ammonia N (kg/sec)	Total Kjeldahl N (kg/sec)	Total NO_3-NO_2 N (kg/sec)	Total Phosphorus (kg/sec)	Dissolved Phosphorus (kg/sec)	Total Organic Carbon (kg/sec)
No. of Obs.	5	5	5	5	5	5	5
Mean	1,414	-----	0.0419	0.0231	0.0093	0.0022	0.2481
Median	1,439	n.d.	0.0486	0.0147	0.0057	0.0057	0.1704
Minimum	753	n.d.	0.0210	0.0009	0.0043	0.0043	0.0746
Maximum	2,450	0.0106	0.0603	0.0624	0.0194	0.0194	0.4728

Note: Non-detect values set to 0 for flux calculations.

5.7.3.2.3 Continuous Water Temperature Monitoring of the Niobrara River at USGS Gage Site 06465500 near Verdel, Nebraska

Through an agreement with the USGS, a water temperature monitoring probe was added to the USGS's gage (06465500) on the Niobrara River near Verdel, NE (i.e., near site GTPNFNIOR1). Beginning in April 2005, hourly water temperature measurements were recorded at the site. Plates 338 339, 340, and 341, respectively, plot mean daily water temperature and river discharge determined for 2005, 2006, 2007, and 2008.

5.7.3.3 <u>Estimated Total Inflow Conditions</u>

The water quality conditions of the Missouri River inflow to Gavins Point Reservoir are estimated from the water quality conditions of the Missouri River above its confluence with the Niobrara River, and the Niobrara River above its confluence with the Missouri River. Streamflow in the Missouri River below the confluence of the Niobrara River is estimated by adding streamflows in each river. Water quality conditions are estimated by flow-weighted averaging.

5.7.3.3.1 Inflow Nutrient Flux Conditions

The estimated nutrient flux rates of the Missouri River inflow to Gavins Point Reservoir are given in Table 5.22. The estimates in Table 5.22 were determined by flow-weighting the results provided in Tables 5.20 and 5.21. This assumes that mean, median, minimum, and maximum conditions in the Missouri and Niobrara Rivers represented in Tables 5.20 and 5.21 occur concurrently.

Table 5.22. Summary of nutrient flux rates (kg/sec) estimated for the Missouri River inflow to Gavins Point Reservoir during the 5-month period May through September 2008.

Statistic	Total Flow (cfs)	Total Ammonia N (kg/sec)	Total Kjeldahl N (kg/sec)	Total NO_3-NO_2 N (kg/sec)	Total Phosphorus (kg/sec)	Total Organic Carbon (kg/sec)
Mean	14,797	0.0145	0.1541	0.0121	0.0151	3.7178
Median	17,682	0.0165	0.1476	0.0012	0.0174	3.1118
Minimum	3,765	n.d.	0.0247	0.0002	0.0028	1.9004
Maximum	24,983	0.0342	0.2937	0.0393	0.0249	7.3300

Note1: Values are flow-weighted averages of the values provided in Tables 5.20 and 5.21.

5.7.3.3.2 Mean Daily Discharge and Temperature

The estimated mean daily discharge and temperature of the Missouri River inflow to Gavins Point Reservoir for 2005, 2006, 2007, and 2008 are plotted in Plates 342, 343, 344, and 345. The mean daily discharge was estimated by adding the mean daily discharges determined for the Fort Randall Dam outflow and Niobrara River near Verdel, NE at USGS gaging station 06465500. The mean daily temperature was estimated by flow weighting the mean daily water temperatures determined at the two sites.

5.7.4 WATER QUALITY AT THE GAVINS POINT POWERPLANT

5.7.4.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

Plate 346 summarizes the water quality conditions that were monitored on water discharged through Gavins Point Dam during the 5-year period 2004 through 2008. A review of these results indicated no major water quality concerns.

5.7.4.2 Temperature, Dissolved Oxygen, and Dam Discharge Time-Series Plots

Semiannual time-series plots for temperature, dissolved oxygen, and dam discharge monitored at the Gavins Point powerplant during the 5-year period 2004 through 2008 were constructed. Water temperatures showed seasonal warming and cooling through each calendar year (Plates 347 - 356). Dissolved oxygen levels remained relatively high and stable during the winter, steadily declined through the spring and summer, and steadily increased during the fall (Plates 357 - 366). Except for a few occasions in the spring, the lowest dissolved oxygen levels occurred during mid- to late July. The higher winter, declining spring, and increasing fall dissolved oxygen concentrations are attributed to decreasing dissolved oxygen solubility with warmer water temperatures. The lower dissolved oxygen concentrations in July may be associated with degradation in the hypolimnion when limited thermal stratification is able to become established. There appeared to be little correlation between discharge rates and measured water temperature and dissolved oxygen concentrations (Plates 347 - 366).

5.7.4.3 Comparison of Monitored Inflow and Outflow Temperatures of the Missouri River at Gavins Point Reservoir

Plates 367, 368, 369, and 370, respectively, plot the mean daily water temperatures estimated for the Missouri River inflow to Gavins Point Reservoir and monitored at the Gavins Point Dam powerplant (site GTPPP1) for 2005, 2006, 2007, and 2008. Inflow temperatures of the Missouri River to Gavins Point Reservoir tend to be at little cooler than the outflow temperatures of Gavins Point Dam during the spring to mid-summer. Outflow temperatures of the Gavins Point Dam discharge tend to be a little cooler than the Missouri River inflow temperatures in the late-summer and fall.

5.8 COMPARISON OF EXISTING WATER QUALITY CONDITIONS AT THE MAINSTEM SYSTEM RESERVOIRS

During 5-year period of 2004 through 2008 conditions in the upper Missouri River basin, where the Mainstem System reservoirs are located, were characterized by severe drought early in the period and more "normal" precipitation and runoff later in the period. During this period, Mainstem System reservoirs experienced historic low pool elevations and water in storage dropped to 46 percent of the Mainstem System storage capacity in February 2007. By August 2008 storage had recovered to 63 percent of the Mainstem System storage. *(Note: Storage has continued to increase during 2009 and Mainstem System storage reached 79 percent of storage capacity).* During the 5-year period reduced pool levels and reservoir volumes were especially pronounced at the upper three Mainstem System reservoirs: Fort Peck, Garrison, and Oahe. Drought induced reduction in reservoir volumes could reasonably be expected to have water quality ramifications due to reductions in the pollution assimilative capacity of the reservoirs and exposure of previously flooded sediments. The final impact of the existing drought on water quality conditions at the Mainstem System reservoirs is still to be determined; however, monitoring of existing water quality conditions does not indicate major concerns other than the maintenance of coldwater fishery habitat in Garrison Reservoir.

5.8.1 IMPAIRMENT OF DESIGNATED WATER QUALITY DEPENDENT BENEFICIAL USES

The attainment of water quality standards at the Mainstem System Projects, based on water quality conditions monitored over the 5-year period 2004 to 2008 by the District, is summarized in Table 5.23. Water quality standards attainment was defined as whether the designated beneficial uses in State water quality standards were impaired based on the monitored water quality conditions and defined State impairment assessment criteria. It is noted that the "official" determination of whether designated beneficial uses are impaired, pursuant to the Federal CWA, is made by the States pursuant to their Section 305(b) and Section 303(d) assessments (See Table 1.3). As shown in Table 1.3, the State of Montana currently list recreation in Fort Peck Reservoir as being impaired due to aquatic plants (native). Monitored water quality conditions by the District during the 5-year period 2004 through 2008 do not support the State's impairment listing of recreation.

Table 5.23. Summary of impairment of designated beneficial uses (i.e., water quality standards attainment) based on existing water quality conditions monitored at the Mainstem System projects over the 5-year period 2004 through 2008. (Note: "Official" identification of impaired water bodies is defined in State prepared Section 305(b) and Section 303(d) assessments – See Table 1.3.)

	Recreation(1)	**Coldwater Aquatic Life**	**Warmwater Aquatic Life**	**Domestic Water Supply**	**Agricultural Water Supply**	**Industrial Water Supply**
Fort Peck Reservoir	Unknown	Not Assigned(2)	Full Support	Full Support	Full Support	Full Support
Fort Peck Dam Tailwaters	Unknown	Full Support	Full Support	Full Support	Full Support	Full Support
Garrison Reservoir	Unknown	Impaired(3)	Full Support	Full Support	Full Support	Full Support
Garrison Dam Tailwaters	Unknown	Threatened(4)	Threatened(4)	Full Support	Full Support	Full Support
Oahe Reservoir	Unknown	Full Support	Full Support	Full Support	Full Support	Full Support
Oahe Dam Tailwaters	Unknown	Impaired(5)	Full Support	Full Support	Full Support	Full Support
Big Bend Reservoir	Unknown	Impaired(6)	Full Support	Full Support	Full Support	Full Support
Big Bend Dam Tailwaters	Unknown	Not Assigned	Full Support	Full Support	Full Support	Full Support
Fort Randall Reservoir	Unknown	Not Assigned	Full Support	Full Support	Full Support	Full Support
Fort Randall Dam Tailwaters	Unknown	Not Assigned	Threatened(4)	Full Support	Full Support	Full Support
Gavins Point Reservoir	Full Support	Not Assigned	Impaired(7) Threatened(8)	Full Support	Full Support	Full Support
Gavins Point Dam Tailwaters	Unknown	Not Assigned	Full Support	Full Support	Full Support	Full Support

(1) Water quality standards attainment for recreation is based on assessment of collected bacteria data.

(2) The State of Montana has not designated a coldwater aquatic life use to Fort Peck Reservoir. A coldwater fishery and associated aquatic life do exist in Fort Peck Reservoir and seemingly are an existing use. Monitored water quality conditions indicate that it is currently fully supported.

(3) Coldwater aquatic life in Garrison Reservoir is seemingly impaired by warm water temperatures and low dissolved oxygen levels during late summer. This is believed a result of reduced hypolimnetic volume associated with low pool elevations and the degradation of dissolved oxygen in the hypolimnion.

(4) Aquatic life uses in the Garrison and Fort Randall Dam tailwaters may be threatened by low dissolved oxygen levels during late summer. Water discharged from both dams is drawn from the bottom of Garrison and Fort Randall Reservoirs. The reservoirs thermally stratify during the summer and the lower depths of the hypolimnion experience dissolved oxygen degradation as the summer progresses.

(5) Oahe Reservoir thermally stratifies in the summer and coldwater aquatic life is supported in the reservoir's hypolimnion. However, the power tunnel portals at Oahe Dam are located about 110 feet above the bottom of the reservoir and dam discharges during the summer commonly draw warmer water from the metalimnion and epilimnion – especially when pool elevations are low. Thus, water temperatures in the Oahe Dam tailwaters are not supportive of coldwater aquatic life during mid- to late-summer.

(6) Big Bend Reservoir generally does not exhibit significant thermal stratification in the summer; therefore, a coldwater hypolimnion does not usually form. The lack of significant summer thermal stratification at the reservoir is attributed to its relative shallowness and the high discharges released through Big Bend Dam associated with its operation to meet peak power demands. Due to the lack of significant summer thermal stratification, ambient water temperatures in Big Bend Reservoir are not cold enough to support coldwater permanent fish life propagation, as defined by State water quality criteria. Consideration should be given to reclassify Big Bend Reservoir for a warmwater permanent fish life propagation use based on a use attainability assessment of "natural conditions" regarding ambient water temperature.

(7) Warmwater aquatic life (i.e., aesthetics) is impaired due to nutrients based on monitored total phosphorus, total nitrogen, and chlorophyll *a* levels.

(8) Warmwater aquatic lie is seemingly threatened by sedimentation of Gavins Point Reservoir as the volume loss from the "as-built" multiple use pool is approaching 25 percent (i.e., 23.4%).

5.8.2 GENERAL WATER QUALITY CONDITIONS IN THE RESERVOIRS

Table 5.24 summarizes general water quality conditions at the Mainstem System reservoirs based on the water quality monitoring conducted over the 5-year period 2004 through 2008. The four largest reservoirs (i.e., Fort Peck, Garrison, Oahe, and Fort Randall) exhibit characteristics typical of dimictic lakes (Wetzel, 2001). The four reservoirs exhibit summer and winter thermal stratification separated by periods of complete mixing during the spring and fall turnover periods. A large quiescent hypolimnion forms during the summer in the three larger reservoirs (i.e., Fort Peck, Garrison, and Oahe) with a smaller hypolimnion forming in Fort Randall. The formation of a smaller hypolimnion in Fort Randall Reservoir, as compared to the three other reservoirs, is attributed to its lesser maximum depth and volume. Due to their shallower depths, Big Bend and Gavins Point Reservoirs appears to be discontinuous polymixic, with periods of summer thermal stratification forming and breaking down as climatic factors change. Big Bend Reservoir does not typically exhibit prolonged summer thermal stratification due to the high discharge rates that occur through Big Bend Dam for power production. Moderate hypolimnetic dissolved oxygen degradation regularly occurs in Garrison and Fort Randall Reservoirs. Only minor hypolimnetic dissolved oxygen degradation appears to occur in Fort Peck, Oahe, and Big Bend Reservoirs. Significant dissolved oxygen degradation can occur in Gavins Point Reservoir during the summer when thermal stratification persists. Water quality conditions of summer discharges from Garrison and Fort Randall Dams are highly correlated to dam discharge rates. This high degree of correlation of summer water quality conditions of discharged water with the dam discharge rate is not evident at the other four Mainstem System dams. The high degree of correlation at Garrison and Fort Randall Dams is attributed to each dam having a near-bottom withdrawal from their impounded reservoirs. The vertical extent of the withdrawal zone in these two reservoirs is dependent on the dam discharge rate. The lacustrine areas of the five upper reservoirs all appear to be mesotrophic, with only Gavins Point being in a eutrophic condition. The prevalence of major phytoplankton groups is similar in all six Mainstem System reservoirs, with diatoms being the most prevalent group.

5.8.3 COMPARISON OF THE EXISTING COLDWATER HABITAT CONDITIONS IN FORT PECK, GARRISON, AND OAHE RESERVOIRS

5.8.3.1 <u>Water Temperature</u>

Near-bottom water temperatures measured at the near-dam, deepwater monitoring sites in Fort Peck, Garrison, and Oahe Reservoirs during the period May through October of 2004 through 2008 were plotted to compare hypolimnetic water temperatures of the three reservoirs (Plate 371). In all 5 years, the near-bottom water temperatures measured in the three reservoirs were similar in May. The near-bottom temperature of all three reservoirs increased every year over the "summer" period. The relative rates at which the near-bottom water warmed in the three reservoirs remained fairly consistent over the 5 years; Garrison had the highest rate of warming, Oahe had the lowest, and the rate of warming of Fort Peck was in between (Plate 371).

Water temperature-depth profiles measured at the near-dam, deepwater locations at the three reservoirs were used to determine the depth at which water temperatures of 15°C or less occurred. Plate 372 shows a plot of the 15°C water temperature isopleths for Fort Peck, Garrison, and Oahe Reservoirs for 2004 through 2008. All three reservoirs exhibited surface water temperatures at or below 15°C in May of all 5 years (Plate 372). After May of each year, the 15°C isopleths in all three reservoirs generally moved downward (i.e., 15°C water temperature occurred at a greater depth) through the "summer" period until fall turnover of the reservoirs occurred. The rate of decline of the 15°C isopleths at Garrison was greater than at Fort Peck and Oahe in 2004, 2005, and 2008 (Plate 372). In 2006 and 2007 the rate of decline of the 15°C isopleths was similar in all three reservoirs (Plate 297). The decreasing rate in the decline of the 15°C isopleths at Garrison Reservoir, in comparison to Fort Peck and Oahe Reservoirs, in 2006 and 2007 is attributed to the short-term water management measures implemented at Garrison Dam to enhance coldwater habitat in Garrison Reservoir. Water temperatures monitored in 2008 are believed to be impacted by the high inflows to the reservoirs that occurred in late-spring and early summer.

Table 5.24. Summary of general water quality conditions monitored at the Mainstem System reservoirs over the 5-year period 2004 through 2008. (Note: Record low pool levels occurred during the 5-year period due to severe drought in the western Untied States where the reservoirs are located.)

	Fort Peck	Garrison	Oahe	Big Bend	Fort Randall	Gavins Point
Maximum reservoir depth near the dam when pool elevation is at the top of Carryover Multiple Use Zone.	204 ft	168 ft	193 ft	75 ft	123 ft	48 ft
Minimum daily pool elevation recorded during the 5-year period 2004 through 2008.	2196.2 ft-msl	1805.8 ft-msl	1570.2 ft-msl	1419.4 ft-msl	1336.9 ft-msl	1204.9 ft-msl
Maximum reservoir depth near the dam at the minimum pool elevation recorded during the 5-year period 2004 through 2008.	166 ft	136 ft	155 ft	74 ft	110 ft	45 ft
Extent of hypolimnion formed during summer thermal stratification period	Large (Plate 11)	Large (Plate 71)	Large (Plate 145)	Very Small (Plate 204)	Moderate (Plate 261)	Small (Plate 317)
Extent of dissolved oxygen degradation in the hypolimnion just prior to "fall turnover" of the reservoir	Minor (Plate 16)	Moderate (Plate 77)	Minor (Plate 151)	Minor (Plate 209)	Moderate (Plate 266)	Moderate (Plate 322)
Correlation of dam discharge water quality conditions to dam discharge rates during the summer	Low (Plates 31-50)	High (Plates 96-119)	Low (Plates 171-1190)	Low (Plates 224-245)	High (Plates 283-301)	Low (Plates 347-366)
Lake trophic status[(1)]	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Eutrophic
Average TSI score[(2)]	47	49	46	49	47	62
Most prevalent phytoplankton group sampled[(3)]	Bacillariophyta	Bacillariophyta	Bacillariophyta	Bacillariophyta	Bacillariophyta	Bacillariophyta
Percent of samples where Cyanobacteria was the most prevalent phytoplankton group based on collected biovolume[(3)]	8%	0%	8%	9%	4%	4%
Percent of samples where Cyanobacteria were 10% or more of the collected phytoplankton biovolume[(3)]	32%	8%	21%	30%	9%	17%

(1) Based on near-dam water quality conditions in the reservoir.
(2) TSI = Trophic State Index (see text for explanation). Based on near-dam water quality conditions in the reservoir.
(3) Based on phytoplankton samples collected near the dam of each reservoir.

The rate of hypolimnetic warming of the three reservoirs appears to be related to the depth of water withdrawal from the reservoir. Garrison Reservoir has the deepest level of withdrawal (i.e., 2 feet above the reservoir bottom) and, except for 2006 and 2007, had the highest rate of warming. Oahe Reservoir has the shallowest level of withdrawal (i.e., 110 feet above the reservoir bottom) and had the lowest rate of warming. Fort Peck Reservoir has an intermediary level of withdrawal (i.e., 65 feet above the reservoir bottom) and had an intermediate rate of warming. In 2006 and 2007, the implemented short-term water quality management measures at Garrison Dam (i.e., plywood barriers on trash racks) resulted in an intermediary level of withdrawal, and in 2006 and 2007 the rate of hypolimnetic warming at Garrison Reservoir was similar to Fort Peck Reservoir. The near-bottom withdrawal of water from Garrison Reservoir, absent the trash-rack plywood barriers, undoubtedly causes mixing within the hypolimnion as water is discharged through the dam and evacuated from lower levels of the hypolimnion. This mixing induces the transfer of heat within the reservoir's hypolimnion and into it from the metalimnion. The elevation of water withdrawal from Oahe Reservoir is generally at or above the thermocline, especially during low pool levels, and extensive mixing and warming of the hypolimnion is not induced. Water withdrawn from Fort Peck Reservoir and from Garrison Reservoir with the trash-rack plywood barriers in place is from the upper depths of the hypolimnion, and some withdrawal-induced mixing and warming of the hypolimnion may take place.

5.8.3.2 Dissolved Oxygen

As was done for water temperature, near-bottom dissolved oxygen concentrations measured at the near-dam, deepwater monitoring sites in Fort Peck, Garrison, and Oahe Reservoirs during May through October of the 5-period 2004 through 2008 were plotted to compare the hypolimnetic dissolved oxygen conditions of the three reservoirs (Plate 373). For all 5 years, the near-bottom dissolved oxygen concentrations measured in Garrison Reservoir ended the summer period (i.e., just prior to fall turnover) with lower dissolved oxygen levels than the other two reservoirs (Plate 373). The hypolimnetic dissolved oxygen levels of all three reservoirs decreased every year over the summer period. The relative rates of dissolved oxygen degradation in the near-bottom water of the three reservoirs over the summer periods evaluated were somewhat consistent. The hypolimnetic dissolved oxygen degradation rates in Fort Peck and Oahe Reservoirs appeared similar and less those present in Garrison Reservoir (Plate 373). It is believed the near-bottom withdrawal of water at Garrison Reservoir may draw water with low dissolved oxygen levels to the dam from the middle reaches of the reservoirs faster than at Fort Peck and Oahe Reservoirs.

6 LOWER MISSOURI RIVER: GAVINS POINT DAM TO RULO, NE

6.1 CHANNEL CHARACTERISTICS AND TRIBUTARIES

The Missouri River between Gavins Point Dam (RM 811.1) and Rulo, NE (RM498.0) flows in an east-southeasterly to south-southeasterly direction. Major tributaries to the Missouri River below Gavins Point Dam, moving downstream, include: James River (South Dakota) at RM 800.8, Vermillion River (South Dakota) at RM 772.0, Big Sioux River (South Dakota and Iowa) at RM 734.0, Floyd River (Iowa) at RM 731.1, Little Sioux River (Iowa) at RM 669.2, Platte River (Nebraska) at RM 594.8, and Nishnabotna River (Iowa) at RM 542.0. Extensive bed degradation has occurred in the upper areas of this Missouri River reach because river sediment is captured above Gavins Point Dam. Another factor is the substantial Missouri River channel shortening that occurred as part of the downstream Missouri River Bank Stabilization and Navigation Project. Gradual armoring of the riverbed has reduced the rate of channel degradation. Since 1965, approximately 10 feet of stage reduction has occurred for a discharge of 30,000 cfs in the Sioux City, IA area. During this period channel degradation of the Missouri River downstream in the Omaha, NE (RM 615.9) area has been non-existent. This reach of the Missouri River can be separated into three distinct sub reaches: the Missouri River National Recreational River, Kensler's Bend, and the Missouri River Navigation Channel reaches.

6.1.1 MISSOURI RIVER NATIONAL RECREATION RIVER REACH

The 59-mile reach of the Missouri River downstream of Gavins Point Dam starting at RM 811.0 down to Ponca, NE (RM 752.0) has been designated a National Recreational River under the Federal Wild and Scenic Rivers Act. This reach of the river has not been channelized by construction of dikes and revetments, and has a meandering channel with many chutes, backwater marshes, sandbars, islands, and variable current velocities. Snags and deep pools are also common. Although this portion of the river includes some bank stabilization structures, the river remains fairly wide. Bank erosion rates since the closure of Gavins Point Dam in 1956 have averaged 132 acres per year between Gavins Point Dam and Ponca, compared to a pre-dam rate of 202 acres per year. The rate of erosion had been declining since 1975 and then dramatically increased during the high flow years of 1995 through 1997.

6.1.2 KENSLER'S BEND REACH

The Kensler's Bend reach of the Missouri River extends from Ponca, Nebraska (RM 752.0) to above Sioux City, IA (RM 735.0). The Missouri River banks have been stabilized with dikes and revetments through this reach, but it has not been channelized.

6.1.3 MISSOURI RIVER NAVIGATION CHANNEL REACH

The reach of the Missouri River from the end of the Kensler's Bend reach (RM 735.0) to Rulo, NE (RM 498.0) has been modified over its entire length by an intricate system of dikes and revetments designed to provide a continuous navigation channel without the use of locks and dams. This reach is managed by the Corps under the Missouri River Bank Stabilization and Navigation Project. In addition to the primary authorization to maintain a navigation channel (9 ft deep by 300 ft wide) downstream from Sioux City, IA to the mouth of the Missouri River, there are authorizations to stabilize the river's banks.

6.2 FLOW REGULATION

Releases from Gavins Point Dam follow the same pattern as those from Fort Randall Dam because there is little active storage in Gavins Point Reservoir. Releases from both dams are based on the amount of water in Mainstem System storage, which governs how much water will be released to meet service demands in the portion of the lower Missouri River from Sioux City, IA to St. Louis, MO. Constraints for flood control, threatened and endangered bird nesting, and fish spawning also are factors governing releases. Releases from Gavins Point Dam generally fall into three categories: navigation, flood evacuation, and nonnavigation releases.

6.2.1 MAINSTEM SYSTEM SERVICE LEVEL

To facilitate appropriate application of multipurpose regulation criteria to the Mainstem System, a numeric "service level" has been adopted since the Mainstem System was first filled in 1967. Quantitatively, a full service level approximates the water release rate necessary to achieve a normal 8-month navigation season with average downstream tributary flow contributions. For "full-service" and "minimum service" levels, the numeric service level values are, 35,000 cfs (cubic feet per second) and 29,000 cfs, respectively. This service level is used for selection of appropriate flow target values at previously established downstream control locations on the Missouri River. There are four flow target locations selected below Gavins Point Dam to assure that the Missouri River has adequate water available for the entire downstream reach to achieve regulation objectives. The four flow target locations and their flow target discharge deviation from service levels are: Sioux City (-4,000 cfs); Omaha (-4,000 cfs); Nebraska City (+2,000 cfs); and Kansas City (+6,000 cfs). A full-service level of 35,0000 cfs results in target discharges of 31,000 cfs at Sioux City and Omaha; 37,000 cfs at Nebraska City; and 41,000 cfs at Kansas City. Similarly, a minimum-service level of 29,000 cfs results in target values of 6,000 cfs less than the full-service levels at the four target locations. The relation of service levels to the volume of water in Mainstem System storage is as follows:

Date	Water in Mainstem System Storage (MAF)	Service Level (cfs)
March 15	54.5 or more*	35,000 (full-service)
March 15	31.0 to 49.0*	29,000 (minimum-service)
March 15	31.0 or less	No Service
July 1	57.0 or more*	35,000 (full-service)
July 1	50.5 or less*	29,000 (minimum-service)
* Straight-line interpolation defines intermediate service levels between full and minimum service.		

The length of the navigation season is determined by the volume of water in storage as follows:

Date	Water in Mainstem System Storage (MAF)	Season Closure Date at Mouth of Missouri River
March 15	Less than 31.0	No season
July 1	51.5 or more*	December 1 (8-month season)
July 1	41.0 to 46.8*	November 1 (7-month season)
July 1	36.5 or less*	October 1 (6-month season)
* Straight-line interpolation defines intermediate closure date between given values.		

6.2.2 HISTORIC FLOW RELEASES

In the navigation season, which generally runs from April 1 through November 30, releases from Gavins Point Dam are generally 25,000 to 35,000 cfs. In the winter, releases are in the 10,000- to 20,000-

cfs range. In wet years with above-normal upstream inflows, releases are higher to evacuate flood control storage space in upstream reservoirs. Maximum winter releases are generally kept below 24,000 cfs to minimize downstream flooding problems caused by ice jams in the lower river. During the 1987 to 1993 and the 2000 to present droughts, nonnavigation releases were generally in the 8,000- to 9,000- cfs range immediately following the end and preceding the start of the navigation season. During cold weather, releases were increased up to 15,000 cfs, but generally averaged 12,000 cfs over the 3-month winter period from December through February.

6.2.3 FLOW RELEASES FOR WATER QUALITY MANAGEMENT

Generally, Mainstem System release levels necessary to meet downstream water supply purposes exceed the minimum release levels necessary to meet minimum downstream water quality requirements. Tentative flow requirements for satisfactory water quality were first established by the U.S. Public Health Service and presented in the 1951 Missouri Basin Inter-Agency Committee Report on Adequacy of Flows in the Missouri River. These requirements were used in Mainstem System regulation until revisions were made in 1969 by the Federal Water Pollution Control Administration. The Missouri River minimum daily flow requirements for water quality (i.e., dissolved oxygen) that are given below were initially established by the Federal Water Pollution Control Administration in 1969. They were reaffirmed by the U.S. Environmental Protection Agency in 1974 after consideration of: 1) the current status of PL 92-500 programs for managing both point and non-point sources discharging into the river, and 2) the satisfactory adherence to the dissolved-oxygen concentration of 5.0 mg/l. The minimum daily flow requirements listed below are used for Mainstem System regulation purposes.

Location	Dec, Jan, Feb	Mar, Apr	May	Jun, Jul, Aug, Sep	Oct, Nov
Sioux City, IA	1,800 cfs	1,370 cfs	1,800 cfs	3,000 cfs	1,350 cfs
Omaha, NE	4,500 cfs	3,375 cfs	4,500 cfs	7,500 cfs	3,375 cfs
Kansas City, MO	5,400 cfs	4,050 cfs	5,400 cfs	9,000 cfs	4,050 cfs

Low flows in the Missouri River downstream from Gavins Point Dam may affect the ability of powerplants on this reach to meet National Pollutant Discharge Elimination System (NPDES) permit thermal limits for discharging cooling water back into the Missouri River.

6.2.4 FLOW TRAVEL TIMES

For purposes of scheduling releases, approximate open water travel times from Gavins Point Dam are 1.5 days to Sioux City; 3 days to Omaha; 3.5 days to Nebraska City; 5.5 days to Kansas City; and 10 days to the mouth of the Missouri River near St. Louis.

6.3 HISTORIC FLOW CONDITIONS (1967 TO 2008)

Historic flow conditions for the period 1967 through 2008 were determined from Corps and USGS gaging sites along the Missouri River from Gavins Point Dam to Rulo, NE. The gaging sites include: Gavins Point Dam; Omaha; Nebraska City; and Rulo. Box plots showing the distribution of the mean daily flows measured over the 42-year period are shown in Figure 6.1.

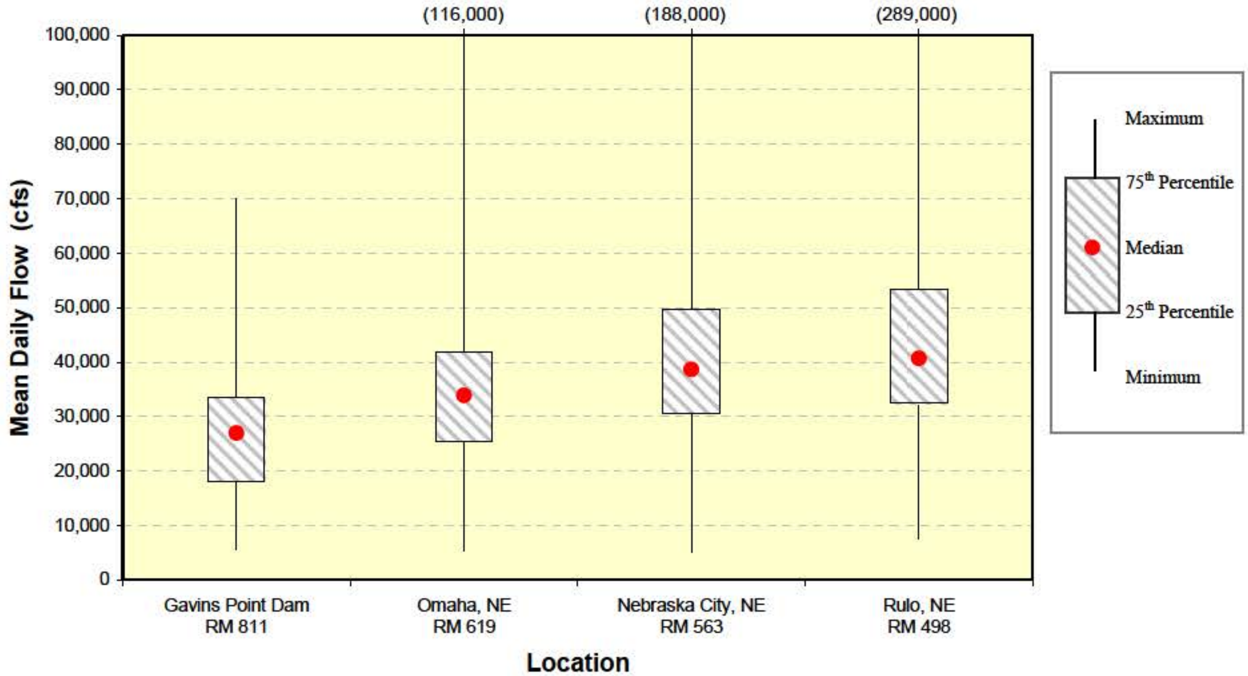

Figure 6.1. Distribution of mean daily flows recorded at gaging sites on the Missouri River at Gavins Point Dam, Omaha, NE, Nebraska City, NE, and Rulo, NE during the 42-year period of 1967 through 2008.

6.4 NATIONAL RECREATION RIVER DESIGNATION PURSUANT TO THE FEDERAL WILD AND SCENIC RIVERS ACT

The 59-mile "natural-channel" reach from Gavins Point Dam to Ponca State Park, NE has been designated as a National Recreational River under the Federal Wild and Scenic Rivers Act (WSRA). The National Park Service (NPS) manages the reach under the WSRA. The justification that supported that this reach of the Missouri River be protected as a recreational river identified its outstanding remarkable recreational, fish and wildlife, aesthetic, historical, and cultural values. Under the WSRA, the U.S. Department of Interior (i.e., NPS) is mandated to administer this reach in a manner that will protect and enhance these values for the benefit and enjoyment of present and future generations.

6.5 STATE DESIGNATIONS AND LISTINGS PURSUANT TO THE FEDERAL CLEAN WATER ACT

Pursuant to the Federal Clean Water Act (CWA), the States of South Dakota, Nebraska, Iowa, and Missouri have designated water quality-dependent beneficial uses, in their State water quality standards, for appropriate reaches of the Missouri River downstream of Gavins Point Dam to Rulo, NE. South Dakota has designated the following uses for all of the Missouri River within the state downstream of Gavins Point Dam: primary contact recreation, warmwater fishery, drinking water supply, and industrial water supply. Nebraska has designated the following uses to the entire length of the Missouri River in Nebraska: primary contact recreation, warmwater aquatic life, agricultural water supply, and aesthetics. It has designated the use of drinking water supply to the river below the confluence of the Niobrara River, and industrial water supply to the river below the confluence of the Big Sioux River. Nebraska has also designated the reach between Gavins Point Dam and Ponca State Park as Outstanding State Resource Waters for "Tier 3" protection under the State's water quality standard's antidegradation

policy. Iowa has designated the following uses to all of the Missouri River in the state: primary contact recreation, warmwater fishery, and high quality state resource water. It has also designated the use of drinking water supply to the river in the area of Council Bluffs, IA. Missouri has designated the following uses to the river: primary contact recreation, warmwater fishery, drinking water supply, agricultural water supply, and industrial water supply. The States of Nebraska, Iowa, and Missouri have listed the Missouri River on their State's Section 303(d) list of impaired waters. The pollutant/stressors identified are pathogens, siltation, habitat loss, Dieldrin, PCBs, and arsenic. The source of siltation and habitat loss is identified as hydrologic modifications and channelization. The source of Dieldrin and PCBs is residual contamination, as both substances have been banned since the 1980's. The identified sources for the pathogens are municipal point sources, agriculture, and urban runoff.

6.6 EXISTING WATER QUALITY CONDITIONS (2004 THROUGH 2008)

The Omaha District, in cooperation with the Nebraska Department of Environmental Quality (NDEQ), conducted fixed-station water quality monitoring at seven sites along the Missouri River from Gavins Point Dam to Rulo, NE during the 5-year period of 2004 through 2008. The location of the seven sites were Gavins Point Dam tailwaters (site GPTRRTW1); near Maskell, NE (site MORRR0774); near Ponca, NE (site MORRR0753); at Decatur, NE (site MORRR0691); at Omaha, NE (site MORRR0619); at Nebraska City, NE (site MORRR0563); and at Rulo, NE (site MORRR0498) (Figure 6.2).

6.6.1 STATISTICAL SUMMARY AND COMPARISON TO APPLICABLE WATER QUALITY STANDARDS CRITERIA

During the 5-year period, water quality samples at the seven sites were collected monthly from October through March and monthly to biweekly from April through September. Plates 374 through 380 summarize the water quality conditions that were monitored at the seven sites: GPTRRTW1, MORRR0774, MORRR0753, MORRR0691, MORRR0619, MORRR563, and MORRR0498. A review of these results indicated no major water quality concerns.

6.6.2 LONGITUDINAL VARIATION IN WATER QUALITY

The distributions of selected parameters measured over the 5-year period were depicted as box plots at each of the seven monitored locations. The parameters plotted include dissolved oxygen, pH, specific conductance, chloride, turbidity, total suspended solids, chemical oxygen demand, total organic carbon, total Kjeldahl nitrogen, total ammonia nitrogen, nitrate-nitrite nitrogen, total phosphorus, atrazine, and metolachlor (Plate 381). For comparison purposes, box plots for the individual parameters measured at each of the seven sites are arranged relative to their respective location in an upstream to downstream order (i.e., GPTRRTW1 = RM811, MORRR0774 = RM774, MORRR0753 = RM753, MORR0691 = RM691, MORR0619 = RM619, MORR0563 = RM563, and MORR0498 = RM498). Four longitudinal trends were categorized based on the constructed longitudinal box plots: 1) parameter exhibits no observable longitudinal trend, 2) parameter slightly decreases in a downstream direction, 3) parameter slightly increases in a downstream direction, and 4) parameter greatly increases in a downstream direction. Parameters that exhibited no observable longitudinal trend included pH, specific conductance, and total ammonia (Plate 381). Dissolved oxygen is the only parameter that slightly decreased in a downstream direction (Plate 381). Parameters that slightly increased in a downstream direction included chloride, chemical oxygen demand, total organic carbon, total Kjeldahl nitrogen, atrazine, and metolachlor (Plate 381). Parameters that greatly increased in a downstream direction included turbidity, total suspended solids, nitrate-nitrite nitrogen, and total phosphorus (Plate 381).

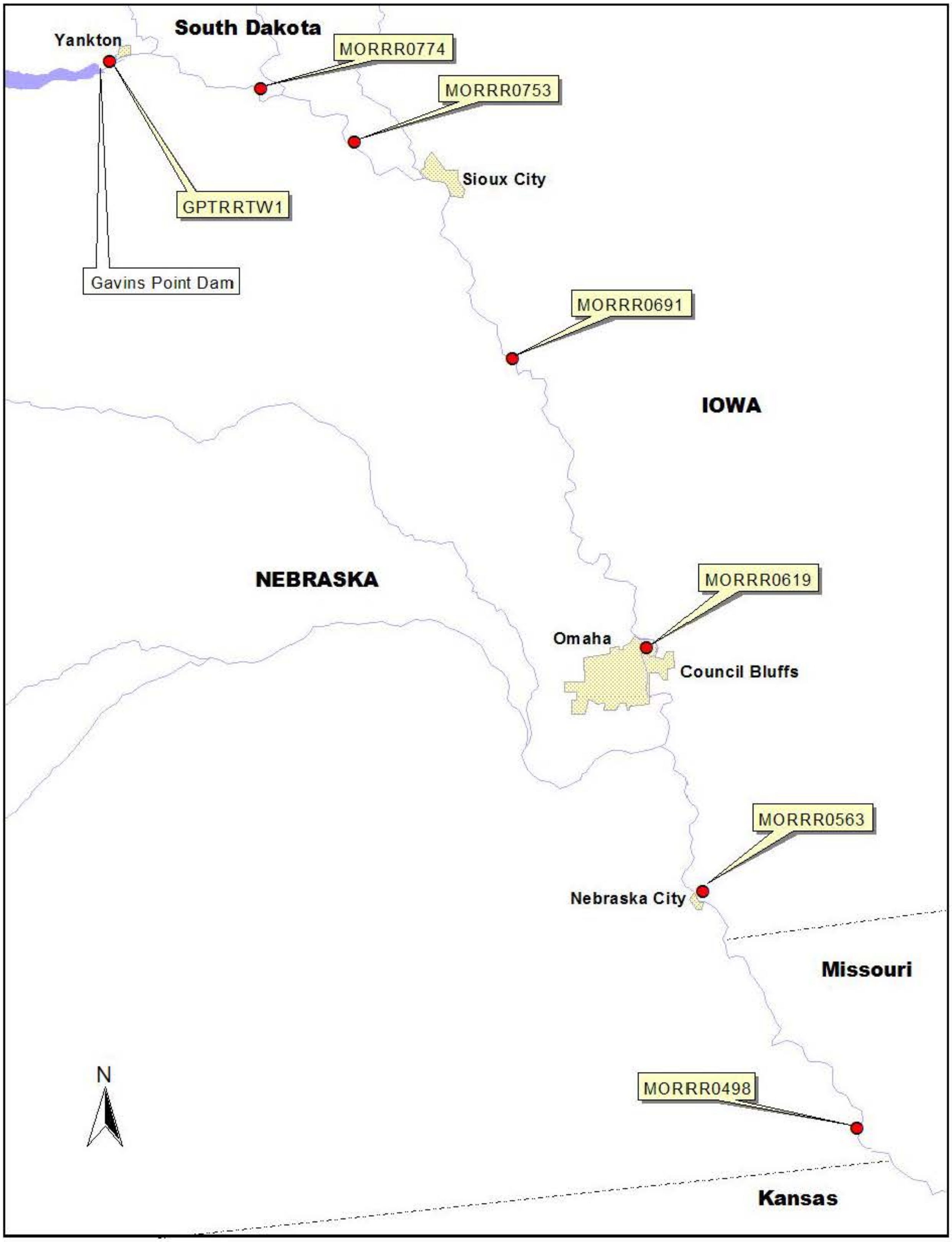

Figure 6.2. Locations of water quality monitoring sites along the Missouri River from Gavins Point Dam to Rulo, NE.

6.7 NUTRIENT FLUX CONDITIONS

Nutrient flux rates along the lower Missouri River from the Gavins Point Dam tailwaters to Rulo, NE were calculated based on monitoring data collected at the seven monitoring locations over the 5-year period 2004 through 2008 (Tables 6.1 - 6.7).

Table 6.1. Summary of nutrient flux rates (kg/sec) calculated for the Missouri River at the Gavins Point tailwaters (i.e., site GTPRRTW1) over the 5-year period 2004 through 2008.

Statistic	Missouri River Flow (cfs)	Total Ammonia N (kg/sec)	Total Kjeldahl N (kg/sec)	Total NO_3-NO_2 N (kg/sec)	Total Phosphorus (kg/sec)	Total Organic Carbon (kg/sec)
No. of Obs.	81	81	81	80	80	79
Mean	18,503	0.0574	0.2820	0.0399	0.0348	1.7636
Median	20,000	0.0304	0.2327	0.0136	0.0224	1.6291
Minimum	8,000	n.d.	n.d.	n.d.	n.d.	0.7128
Maximum	30,963	0.2973	1.3260	0.2718	0.6230	4.6382

n.d. = Nondetectable.
Note: Non-detect values set to 0 for flux calculations.

Table 6.2. Summary of nutrient flux rates (kg/sec) calculated for the Missouri River near Maskell, NE (i.e., site MORRR0774) over the 5-year period 2004 through 2008.

Statistic	Missouri River Flow (cfs)	Total Ammonia N (kg/sec)	Total Kjeldahl N (kg/sec)	Total NO_3-NO_2 N (kg/sec)	Total Phosphorus (kg/sec)	Total Organic Carbon (kg/sec)
No. of Obs.	74	74	74	74	73	72
Mean	20,479	0.0671	0.3366	0.0746	0.0474	2.0351
Median	22,007	0.0364	0.2888	0.0417	0.0366	2.1428
Minimum	9,161	n.d.	n.d.	n.d.	n.d.	0.5718
Maximum	31,082	0.3023	0.9048	0.5503	0.2015	4.2766

n.d. = Nondetectable.
Note: Non-detect values set to 0 for flux calculations.

Table 6.3. Summary of nutrient flux rates (kg/sec) calculated for the Missouri River near Ponca, NE (i.e., site MORRR0753) over the 5-year period 2004 through 2008.

Statistic	Missouri River Flow (cfs)	Total Ammonia N (kg/sec)	Total Kjeldahl N (kg/sec)	Total NO_3-NO_2 N (kg/sec)	Total Phosphorus (kg/sec)	Total Organic Carbon (kg/sec)
No. of Obs.	72	72	72	72	71	70
Mean	20,863	0.0701	0.4056	0.0660	0.0698	2.2604
Median	22,669	0.0322	0.3366	0.0141	0.0455	2.3071
Minimum	9,247	n.d.	0.0970	n.d.	n.d.	0.7571
Maximum	31,661	0.3765	1.5858	0.6820	0.3310	5.3941

n.d. = Nondetectable.
Note: Non-detect values set to 0 for flux calculations.

Table 6.4. Summary of nutrient flux rates (kg/sec) calculated for the Missouri River at Decatur, NE (i.e., site MORRR0691) over the 5-year period 2004 through 2008.

Statistic	Missouri River Flow (cfs)	Total Ammonia N (kg/sec)	Total Kjeldahl N (kg/sec)	Total NO_3-NO_2 N (kg/sec)	Total Phosphorus (kg/sec)	Total Organic Carbon (kg/sec)
No. of Obs.	81	81	81	80	80	78
Mean	24,551	0.1026	0.7133	0.8119	0.1492	2.9065
Median	26,100	0.0495	0.5257	0.4588	0.0903	2.7588
Minimum	11,500	n.d.	0.1811	n.d.	n.d.	0.7140
Maximum	42,400	0.5154	4.6106	5.8897	1.0123	10.8592

n.d. = Nondetectable.
Note: Non-detect values set to 0 for flux calculations.

Table 6.5. Summary of nutrient flux rates (kg/sec) calculated for the Missouri River at Omaha, NE (i.e., site MORRR0619) over the 5-year period 2004 through 2008.

Statistic	Missouri River Flow (cfs)	Total Ammonia N (kg/sec)	Total Kjeldahl N (kg/sec)	Total NO_3-NO_2 N (kg/sec)	Total Phosphorus (kg/sec)	Total Organic Carbon (kg/sec)
No. of Obs.	82	82	82	81	81	80
Mean	27,663	0.1265	0.9529	1.5032	0.2607	3.5031
Median	28,100	0.0425	0.6297	0.8971	0.1240	2.9602
Minimum	13,300	n.d.	n.d.	n.d.	0.0242	1.0385
Maximum	58,400	0.7718	6.6808	7.7722	2.4805	16.8027

n.d. = Nondetectable.
Note: Non-detect values set to 0 for flux calculations.

Table 6.6. Summary of nutrient flux rates (kg/sec) calculated for the Missouri River at Nebraska City, NE (i.e., site MORRR0563) over the 5-year period 2004 through 2008.

Statistic	Missouri River Flow (cfs)	Total Ammonia N (kg/sec)	Total Kjeldahl N (kg/sec)	Total NO_3-NO_2 N (kg/sec)	Total Phosphorus (kg/sec)	Total Organic Carbon (kg/sec)
No. of Obs.	83	83	83	82	82	81
Mean	34,520	0.1731	1.6137	1.8220	0.5148	4.6340
Median	33,300	0.0983	0.9189	1.2046	0.2282	3.3736
Minimum	16,700	n.d.	0.3263	0.0407	0.0729	1.2460
Maximum	117,000	0.9424	12.7881	10.9328	5.6321	26.5038

n.d. = Nondetectable.
Note: Non-detect values set to 0 for flux calculations.

Table 6.7. Summary of nutrient flux rates (kg/sec) calculated for the Missouri River at Rulo, NE (i.e., site MORRR0498) over the 5-year period 2004 through 2008.

Statistic	Missouri River Flow (cfs)	Total Ammonia N (kg/sec)	Total Kjeldahl N (kg/sec)	Total NO_3-NO_2 N (kg/sec)	Total Phosphorus (kg/sec)	Total Organic Carbon (kg/sec)
No. of Obs.	82	82	82	81	81	80
Mean	36,250	0.1696	1.5988	2.1512	0.5119	4.4635
Median	33,475	0.0736	0.9881	1.5495	0.2615	3.3799
Minimum	17,500	n.d.	0.3270	0.0295	0.0595	0.9682
Maximum	131,000	1.1322	11.1163	12.2410	5.2883	25.4971

n.d. = Nondetectable.
Note: Non-detect values set to 0 for flux calculations.

6.8 USGS WATER QUALITY MONITORING IN 2008

During 2008, the USGS conducted "real-time" water quality monitoring at several sites along the lower Missouri River. USGS monitoring sites on the Missouri River from Gavins Point Dam to near Rulo, Nebraska include: Yankton, SD (station 06467500); Ponca, NE (station 06479097); Sioux City, IA (station 06486000); Decatur, NE (station 06601200); Omaha, NE (station 06610000); Nebraska City, NE (Station 06807000); and St. Joseph, MO (station 06818000). "Real-time" water quality parameters that are monitored include water temperature, dissolved oxygen, pH, specific conductance, and turbidity. These water quality data are available at the following USGS web site: *http://ne.water.usgs.gov/missouririverwq/index.html.*

6.9 WATER TEMPERATURES MONITORED ALONG THE LOWER MISSOURI RIVER IN 2008

Mean daily water temperatures were calculated from USGS and USACE data recorded in 2008 at monitoring locations along the lower Missouri River. Figure 6.3 plots 2008 mean daily water temperatures for the Missouri River at Gavins Point Dam; Ponca, NE; Sioux City, IA; Decatur, NE; Omaha, NE; and St. Joseph, MO. Generally, mean daily water temperatures in the Missouri River are about 3 to 4° C warmer at St. Joseph, MO as compared to the discharges from Gavins Point Dam (Figure 6.3).

6.10 ESTIMATED CURRENT NUTRIENT CONCENTRATIONS AND MEAN DAILY LOADS ALONG THE MISSOURI RIVER IN THE OMAHA DISTRICT

Nutrient (i.e., nitrate-nitrite nitrogen, total nitrogen, and total phosphorus) concentrations and mean daily loads for the Missouri River at selected locations in the Omaha District were compiled from monitoring conducted during the 5-year period of 2004 through 2008. The monitored locations along the Missouri River included the following 16 sites (listed in an upstream to downstream order with the river mile given): 1) near Landusky, MT [RM 1921]; 2) at Fort Peck Dam [RM 1771]; 3) Near Williston, ND [RM 1553]; 4) at Garrison Dam [RM 1389]; 5) at Bismarck, ND [RM 1315]; 6) at Oahe Dam [RM 1072]; 7) at Big Bend Dam [RM 986]; 8) at Fort Randall Dam [RM 879]; 9) near Verdel, NE [RM 851]; 10) at Gavins Point Dam [RM 811]; 11) near Maskell, NE [RM 774]; 12) near Ponca, NE [RM 753]; 13) at Decatur, NE [RM 691]; 14) at Omaha, NE [RM 619]; 15) at Nebraska City, NE [RM 563]; and 16) at Rulo, NE [RM 498].

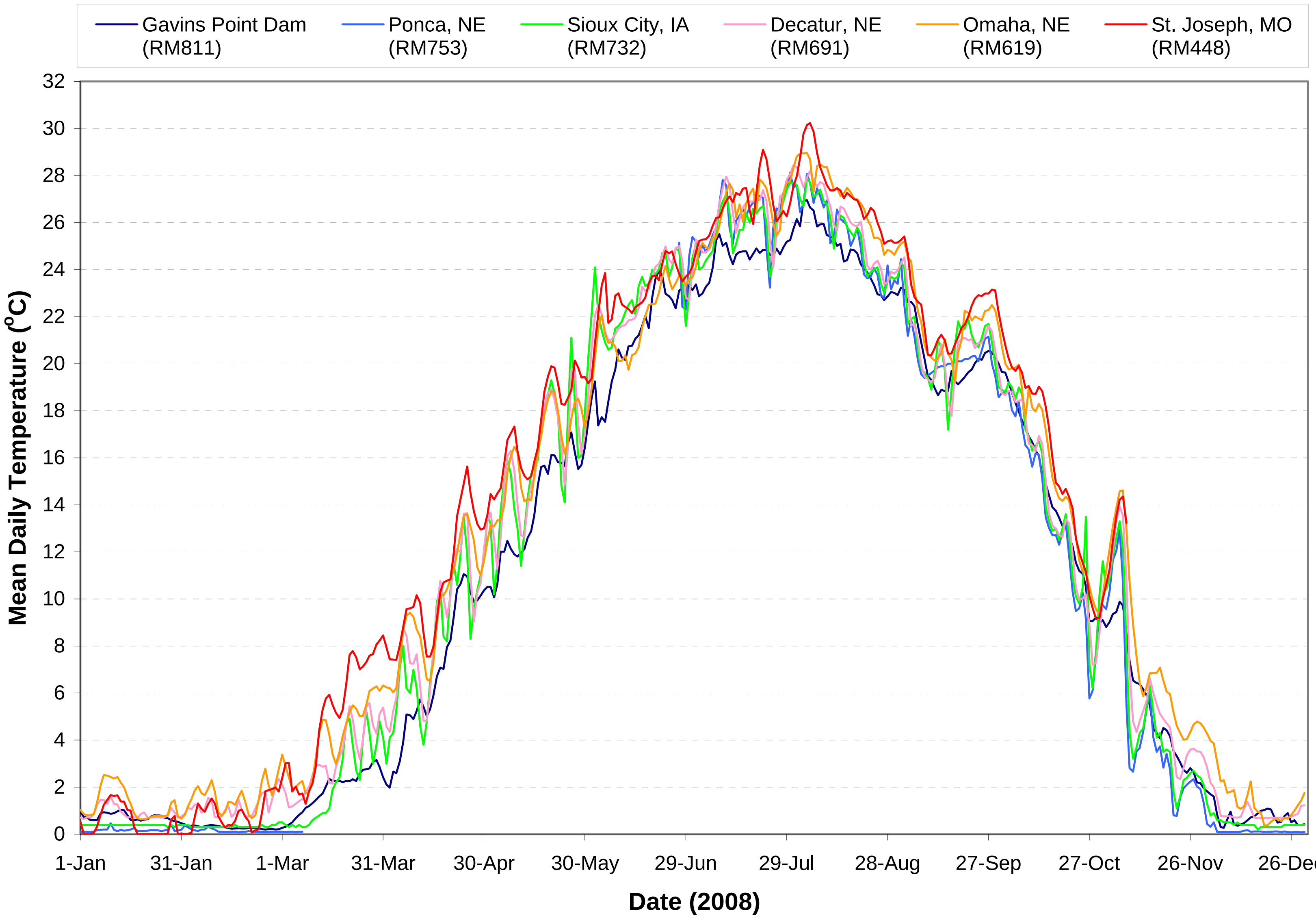

Figure 6.3. Mean daily water temperatures calculated for the lower Missouri River during 2008 at Gavins Point Dam; Ponca, NE; Sioux City, IA; Decatur, NE; Omaha, NE; and St. Joseph, MO.

6.10.1 EXISTING NUTRIENT CONCENTRATIONS MEASURED ALONG THE MISSOURI RIVER

The grab sample measured nitrate-nitrite nitrogen, total nitrogen, and total phosphorus concentrations measured along the Missouri River at the 16 locations during the 5-year period were compiled. Box plots were constructed from the compiled data (Figure 6.4). As seen in Figure 6.4, there is a significant increase in nitrate-nitrite nitrogen levels downstream of Gavins Point Dam; especially downstream of Ponca, NE (RM753). Large cities (i.e., Sioux City, IA and Omaha, NE) and tributary streams draining areas of intensive agriculture are located downstream of Gavins Point Dam. An increase in total phosphorus levels is also seen downstream of Gavins Point Dam (Figure 6.4). Higher levels of total phosphorus were also measured in the Missouri River near Landusky, MT (RM1921 -- inflow to Fort Peck Reservoir) and Williston, ND (RM1553 – inflow to Garrison Reservoir). It is noted that the Yellowstone River enters the Missouri River downstream of Fort Peck Dam and upstream from Williston, ND.

6.10.2 EXISTING NUTRIENT LOADINGS ESTIMATED ALONG THE MISSOURI RIVER

Loadings for nitrate-nitrite nitrogen, total nitrogen (total Kjeldahl nitrogen plus nitrate-nitrite nitrogen), and total phosphorus were estimated for the Missouri River at the 16 locations based on garb sample data collected over the 5-year period. Daily loadings were calculated from the instantaneous flux rates determined for the sites. Figure 6.5 plots the estimated mean daily loads in tons per day at the 16 sites along the Missouri River. The six mainstem reservoirs trap nutrients along the Missouri River and function as nutrient sinks. Nutrient loadings are significant reduced immediately downstream of the six Missouri River mainstem reservoirs (Figure 6.5). The increased loading in the Missouri River at Williston, ND is attributed to the inflow of the Yellowstone River which has no major reservoirs along its entire reach to Yellowstone National Park. The greatly increasing nutrient loads in the Missouri River downstream of Gavins Point Dam are attributed to point and nonpoint source nutrient input to the river.

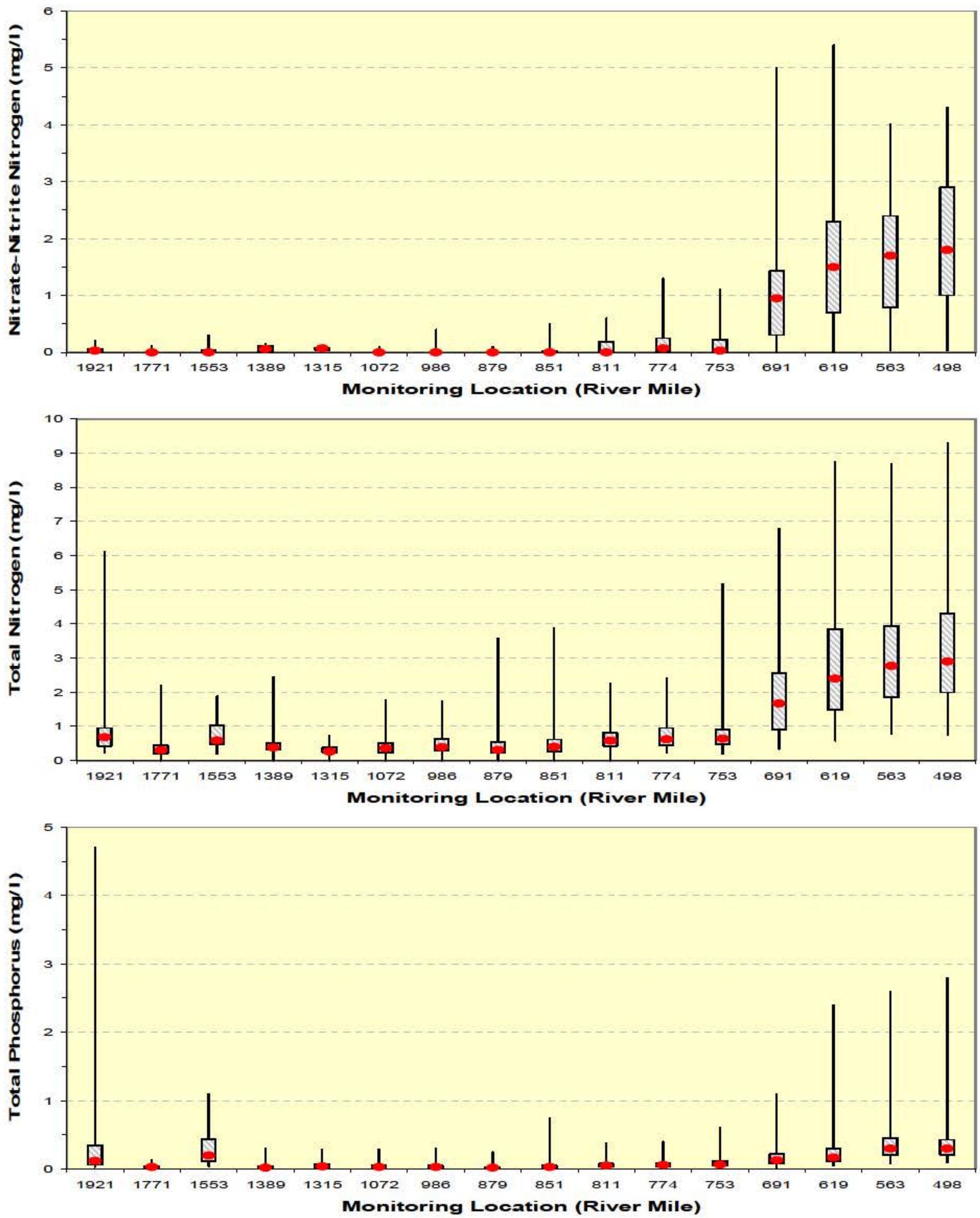

Figure 6.4. Distribution of measured concentrations of nitrate-nitrite nitrogen, total nitrogen, and total phosphorus at 16 locations along the Missouri River from Landusky, MT (RM1921) to Rulo, NE (RM498) during the 5-year period 2004 through 2008. (Box plots represent minimum, 25[th] percentile, 75[th] percentile, and maximum. Red dot is the median value).

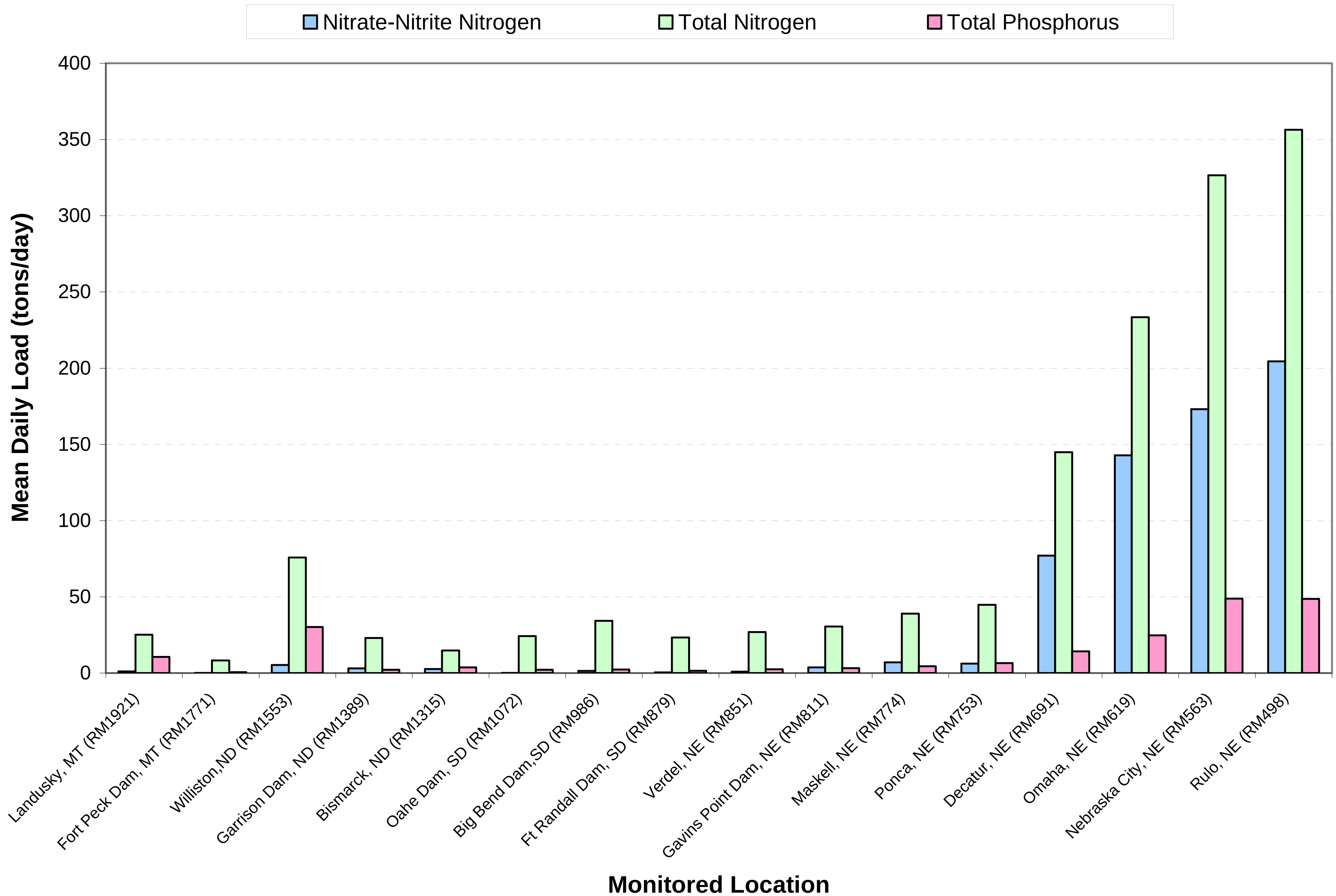

Figure 6.5. Estimated mean daily loads (tons/day) for nitrate-nitrite nitrogen, total nitrogen, and total phosphorus along the Missouri River from near Landusky, MT (RM1921) to Rulo, NE (RM498) for the 5-year period 2004 through 2008.

7 MAINSTEM ANCILLARY LAKES

7.1 LAKE AUDUBON

7.1.1 Background Information

7.1.1.1 Lake Description

Lake Audubon is a sub-impoundment of Garrison Reservoir that is impounded by the Snake Creek Dam. Lake Audubon is located 12 miles northeast of Garrison Dam near the town of Garrison, ND. The Snake Creek Dam was constructed in 1954 with the primary purpose of relocating transportation and utility services inundated by the creation of Garrison Reservoir. A future purpose of Lake Audubon was to facilitate diversion for the purposes of irrigation, water supply, and pollution abatement. Maintenance of a stable sub-impoundment in the Snake River arm of Garrison Reservoir for wildlife and recreational development was defined as a desirable feature. The Snake River Dam has a crest elevation of 1865 ft-msl, and Lake Audubon pool levels are normally kept at about 1847 ft-msl in the summer and 1845 ft-msl in the winter. At pool elevation 1847 ft-msl, Lake Audubon has a surface area of approximately 18,780 acres. The lake is operated in cooperation with the U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service, and the North Dakota Game and Fish Department.

7.1.1.2 Water Quality Standards and Section 303(d) Listings

Pursuant to the Federal CWA, the State of North Dakota has designated Lake Audubon as a Class 2 lake. As such, the lake is to be suitable for the propagation and maintenance of a cool-water fishery (i.e., northern pike and walleye) and associated biota; swimming, boating, and other water recreation; irrigation; stock watering; wildlife; and for municipal or domestic use after appropriate treatment. The State of North Dakota has not placed the lake on the State's Section 303(d) list of impaired waters, but has issued a statewide fish consumption advisory, which applies to Lake Audubon, due to mercury concerns.

7.1.1.3 Ambient Water Quality Monitoring

The District has monitored water quality conditions at Lake Audubon since 1980. Figure 7.1 show the location at Lake Audubon that has been monitored for water quality since 2002. The near-dam site was monitored in 2002 and 2006. It is currently being monitored in 2009.

7.1.2 Existing Water Quality Conditions (2002 through 2008)

7.1.2.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

Plate 382 summarizes the water quality conditions that were monitored in Lake Audubon at the near-dam, deepwater ambient monitoring site (i.e., site AUDLKND1) during 2002 and 2006. A review of these results indicated no water quality concerns.

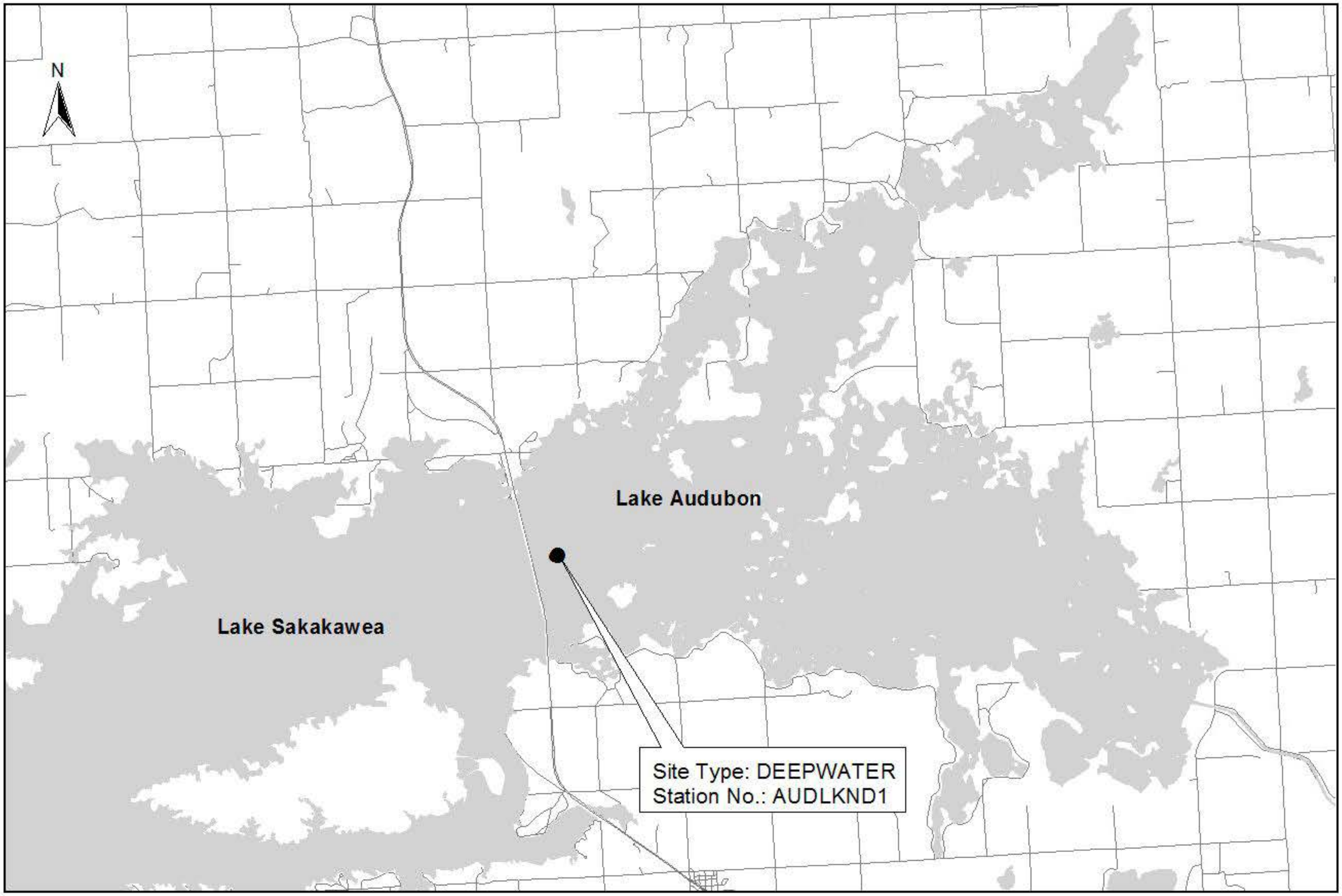

Figure 7.1. Location of water quality monitoring site at Lake Audubon.

7.1.2.2 Summer Thermal Stratification

Existing summer thermal stratification was assessed for Lake Audubon, based on monitoring results obtained at the near-dam, deepwater ambient monitoring site (i.e., site AUDLKND1) during 2002 and 2006. Temperature depth profiles were constructed from water quality data collected during the summer months (Plate 383). It appears a temperature-depth gradient occasionally occurs in Lake Audubon in the near-dam lacustrine area during the summer (Plate 383). When temperature stratification occurred, a thermocline was present near the lake bottom at about 13 meters depth. This indicates the reservoir is probably polymixic. During periods of calm weather in the summer, Lake Audubon likely develops a slight thermal stratification. The thermal stratification seemingly breaks down under windier conditions, given the shallow depth of the reservoir (i.e., 16 meters), allowing the reservoir to mix throughout the water column.

7.1.2.3 Summer Dissolved Oxygen Conditions

Existing summer dissolved oxygen conditions were assessed for Lake Audubon based on monitoring results obtained at the near-dam, deepwater ambient monitoring site during 2002 and 2006. Dissolved oxygen depth profiles were constructed from water quality data collected during the summer months (Plate 384). The measured summer dissolved oxygen-depth profiles exhibited some variability with depth. On occasions, low dissolved oxygen concentrations were measured near the reservoir bottom. The variability of the summer dissolved oxygen-depth profiles is attributed to the probable polymictic nature of the lake. When thermal stratification of the reservoir develops in the summer, significant dissolved oxygen degradation occurs in the near-bottom area of the hypolimnion. The lowest dissolved oxygen concentration measured was 1.7 mg/l, and was measured near the reservoir bottom on July 25, 2006.

7.1.2.4 Lake Trophic Status

Trophic State Index (TSI) values for Lake Audubon were calculated from monitoring data collected during 2002 and 2006 at the near-dam, ambient monitoring site (i.e., site AUDLKND1). Table 7.1 summaries the TSI values calculated for the lake. The TSI values indicate that the near-dam lacustrine area of Lake Audubon is in a mesotrophic to moderately eutrophic state.

Table 7.1. Summary of Trophic State Index (TSI) values calculated for Lake Audubon for 2002 and 2006.

TSI*	No. of Obs.	Mean	Median	Minimum	Maximum
TSI(SD)	7	50	52	43	57
TSI(TP)	7	54	52	41	76
TSI(Chl)	4	44	43	40	50
TSI(Avg)	7	49	48	42	57

* TSI(SD), TSI(TP), and TSI(Chl) are TSI index values based, respectively, on Secchi depth, total phosphorus, and chlorophyll *a* measurements. TSI(Avg) is the average of TSI values irregardless of the parameters available to calculate the average.

Note: See Section 4.1.4 for discussion of TSI calculation.

7.1.2.5 Impairment of Designated Water Quality Beneficial Uses

Based on the State of North Dakota's impairment assessment methodology (Section 4.1.6.3), the water quality conditions monitored in Lake Audubon during 2002 and 2006 do not indicate any impairment of any designated water quality dependent beneficial uses.

7.1.3 WATER QUALITY TRENDS (1980 THROUGH 2006)

Water quality trends over the period of 1980 through 2006 were determined for Lake Audubon for Secchi depth, total phosphorus, chlorophyll *a*, and TSI (i.e., trophic status). The assessment was based on near-surface sampling of water quality conditions in the lake during the months of May through October at the near-dam monitoring site (i.e., site AUDLKND1). Plate 385 displays a scatter-plot of the collected data for the four parameters, a linear regression trend line, and the significance of the trend line (i.e., $\alpha = 0.05$). For the assessment period, Lake Audubon exhibited significant trends for chlorophyll *a* (decreasing) and TSI (decreasing) (Plate 385). No significant trends were detected for Secchi depth and total phosphorus (Plate 385). Over the 27-year period, the lake has generally remained in a moderately eutrophic state (Plate 385).

7.2 LAKE POCASSE

7.2.1 BACKGROUND INFORMATION

7.2.1.1 Lake Description

Lake Pocasse is a sub-impoundment of Oahe Reservoir on Spring Creek that is impounded by the Spring Creek Dam. Lake Pocasse is located in Campbell County, SD, near the town of Pollock. The Spring Creek Dam was built in lieu of a road relocation with a bridge spanning Spring Creek. The purpose of the sub-impoundment was to provide lake and marsh habitat for fish and wildlife management on the Spring Creek bottoms within the Oahe Reservoir pool area. In October 1962, a National Wildlife Refuge was established in the Spring Creek Bottoms, which includes Lake Pocasse. The U.S. Fish and Wildlife Service is responsible for the maintenance and management of wildlife habitat at Lake Pocasse. At the top of the multi-purpose pool (elevation 1614 ft-msl), Lake Pocasse has a surface area of approximately 1,545 acres and a volume of 7,100 acre-feet

7.2.1.2 Water Quality Standards and Section 303(d) Listings

The State of South Dakota has designated the following water quality-dependent beneficial uses for Lake Pocasse in the State's water quality standards: recreation (i.e., immersion and limited-contact), warmwater permanent fish life propagation, fish and wildlife propagation, and stock watering. The State of South Dakota has placed Lake Pocasse on the State's Section 303(d) list of impaired waters as a category 5 waterbody. The identified impaired use is warmwater permanent fish life, with the impairment attributable to nonpoint source pollution. The State has not issued a fish consumption advisory for the lake.

7.2.1.3 Ambient Water Quality Monitoring

The District has not monitored water quality conditions at Lake Pocasse historically or during the period of 2004 through 2008. Low water conditions prevented scheduled monitoring in 2006. Water quality monitoring is currently being conducted in Lake Pocasse in 2009.

7.3 LAKE YANKTON

7.3.1 BACKGROUND INFORMATION

7.3.1.1 Lake Description

Lake Yankton is an "oxbow" lake of the Missouri River that straddles the Nebraska and South Dakota border, just below Gavins Point Dam. The lake was formed when the Gavins Point Dam embankment and the training dike downstream of the dam's outlet were constructed and cutoff a portion of the Missouri River channel. Lake Yankton has a surface area of approximately 250 acres.

7.3.1.2 Water Quality Standards and Section 303(d) Listings

Pursuant to the Federal Clean Water Act, the State of South Dakota has designated the following water quality-dependent beneficial uses for Lake Yankton: recreation (i.e., immersion and limited-contact), warmwater permanent fish life propagation, fish and wildlife propagation, and stock watering. The State of Nebraska has designated the following beneficial uses to Lake Yankton: primary contact recreation, Class I warmwater aquatic life, agricultural water supply, and aesthetics. The uses designated by the States of South Dakota and Nebraska to Lake Yankton are consistent with each other. Neither of the two States has placed Lake Yankton on the State's Section 303(d) list of impaired waters, or has issued fish consumption advisories for the lake.

7.3.1.3 Ambient Water Quality Monitoring

The District has monitored water quality conditions at Lake Yankton since 1982. Figure 7.2 shows the location at Lake Yankton that has been monitored for water quality. This deepwater site was monitored in 2002 and 2006. The lake is currently being monitored in 2009.

7.3.2 EXISTING WATER QUALITY CONDITIONS (2002 THROUGH 2006)

7.3.2.1 Statistical Summary and Comparison to Applicable Water Quality Standards Criteria

Plate 386 summarizes the water quality conditions that were monitored in Lake Yankton at the deepwater ambient monitoring site (i.e., site YAKLKND1) during 2002 and 2006. Based on the criteria for the protection of warmwater aquatic life, 36% of the observations did not meet the dissolved oxygen criterion. The dissolved oxygen measurements that were below the 5.0 mg/l criterion occurred near the lake bottom in the hypolimnion during the summer on occasions when the lake was thermally stratified. Nebraska's dissolved oxygen criteria are not applicable to the hypolimnion when lakes are thermally stratified. The pesticides atrazine and chlorpyrifos were detected on one occasion at levels above State water quality standards criteria.

7.3.2.2 Near-Dam Temperature Depth-Profile Plots

Existing summer thermal stratification was assessed for Lake Yankton, based on monitoring results obtained at the deepwater ambient monitoring site (i.e., site YAKLKND1) during 2002 and 2006. Temperature depth profiles were constructed from water quality data collected during the summer months (Plate 387). Summer thermal stratification appears to be present in Lake Yankton, with water temperatures near the lake bottom being up to 10°C cooler then at the lake surface (Plate 387). The cooler water temperatures near the lake bottom are attributed to groundwater inflow to the lake from "relief wells" along Gavins Point Dam.

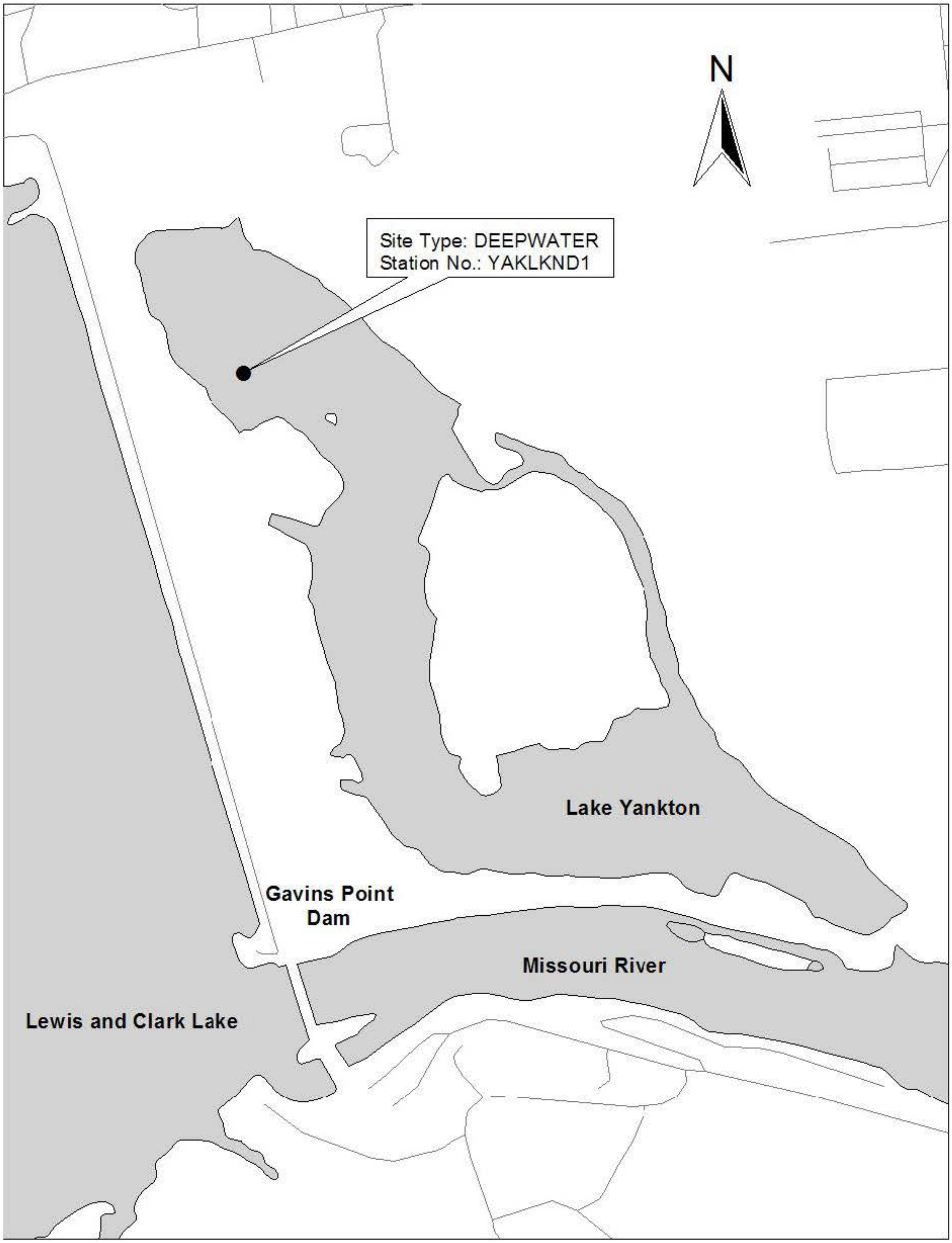

Figure 7.2. Location of water quality monitoring site on Lake Yankton.

7.3.2.3 Near-Dam Dissolved Oxygen Depth Profile Plots

Existing summer dissolved oxygen conditions were assessed for Lake Yankton based on monitoring results obtained at the deepwater ambient monitoring site during 2002 and 2006. Dissolved oxygen depth profiles were constructed from water quality data collected during the months of June, July, August, and September (Plate 388). The measured summer dissolved oxygen-depth profiles exhibited extreme variability with depth. Dissolved oxygen concentrations consistently fell below 1 mg/l in the bottom 1 to 2 meters of the lake (Plate 388). The lowest dissolved oxygen concentration measured was 0.2 mg/l.

7.3.2.4 Comparison of Near-Surface and Near-Bottom Water Quality Conditions

Paired near-surface and near-bottom water quality samples collected from Lake Yankton during the summer in 2002 and 2006 were compared. Near-surface conditions were represented by samples collected within 1-meter of the reservoir surface, and near-bottom conditions were represented by samples collected within 1-meter of the reservoir bottom. The compared samples were collected at site YAKLKND1. During the period a total of 3 to 7 paired samples were collected monthly from June through September. Box plots were constructed to display the distribution of the paired near-surface and near-bottom measurements for the following parameters: water temperature, dissolved oxygen, oxidation-reduction potential (ORP), pH, alkalinity, total ammonia, total phosphorus, total iron, and total manganese (Plate 389). A paired two-tailed t-test was used to determine if the sampled near-surface and near-bottom conditions for the paired samples were significantly different ($\alpha = 0.05$). The sampled near-surface and near-bottom conditions were significantly different for water temperature, dissolved oxygen, ORP, pH, alkalinity, and total iron. Parameters that were significantly lower in the near-bottom water of Gavins Point Reservoir included: water temperature ($p < 0.001$), dissolved oxygen ($p < 0.001$), and pH ($p < 0.001$). Parameters that were significantly higher in the near-bottom water included: alkalinity ($p < 0.01$) and total iron ($p < 0.05$). Small sample size (i.e., 3 paired observations) limited significance testing for ORP, total ammonia, and total manganese. The box plots of these parameters show observable differences between surface and bottom conditions (Plate 389).

7.3.2.5 Lake Trophic Status

Trophic State Index (TSI) values for Lake Yankton were calculated from monitoring data collected during the 2002 and 2006 at the deepwater ambient monitoring site (i.e., site YAKLKND1). Table 7.2 summaries the TSI values calculated for the lake. The TSI values indicate that the Lake Yankton is in a moderately eutrophic to eutrophic state.

Table 7.2. Summary of Trophic State Index (TSI) values calculated for Lake Yankton for 2002 and 2006.

TSI*	No. of Obs.	Mean	Median	Minimum	Maximum
TSI(SD)	15	61	61	51	77
TSI(TP)	15	52	51	41	72
TSI(Chl)	13	53	53	40	81
TSI(Avg)	15	56	57	47	64

* TSI(SD), TSI(TP), and TSI(Chl) are TSI index values based, respectively, on Secchi depth, total phosphorus, and chlorophyll *a* measurements. TSI(Avg) is the average of TSI values the parameters available to calculate the average.

Note: See Section 4.1.4 for discussion of TSI calculation.

7.3.2.6 Bacteria Monitoring at the Training Dike Swimming Beach at Lake Yankton

During the 5-year period 2004 through 2008, bacteria samples were collected weekly from May through September at the Training Dike swimming beach located on Lake Yankton. Table 7.3 summarizes the results of the bacteria sampling. The geometric means were calculated as running geometric means for five consecutive weekly bacteria samples and nondetects were set to 1. The bacteria sampling results were compared to following bacteria criteria for support of "full-body contact" recreation:

Fecal Coliform:

Bacteria of the fecal coliform group should not exceed a geometric mean of 200/100ml, nor equal or exceed 400/100ml, in more than 10% of the samples. These criteria are based on a minimum of five samples taken within a 30-day period.

E. coli:

E. coli bacteria should not exceed a geometric mean of 126/100ml. For increased confidence of the criteria, the geometric mean should be based on a minimum of five samples taken within a 30-day period. Single sample maximum allowable density for designated bathing beaches is 235/100ml.

Based on these criteria and Nebraska's impairment assessment methodology (Section 4.1.6.2), "full-body contact" recreation was fully supported at the Training Dike swimming beach on Lake Yankton during the May through September recreational season during the 5-year period of 2004 through 2008.

Table 7.3. Summary of weekly (May through September) bacteria sampling conducted at the Training Dike swimming beach on Lake Yankton during the 5-year period 2004 through 2008.

	Fecal Coliform Bacteria	***E. coli* Bacteria**
Number of Samples	105	105
Mean	18	16
Median	4	2
Minimum	n.d.	n.d.
Maximum	200	357
Percent of Fecal Coliform samples exceeding 400/100ml	0%	-----
Percent of *E. coli* samples exceeding 235/100ml	-----	1%
• **Geometric Mean**		
Number of Geomeans	86	86
Average	7	6
Median	6	4
Minimum	1	1
Maximum	47	37
Number of Fecal Coliform geomeans exceeding 200/100ml	0	-----
Number of *E. coli* geomeans exceeding 126/100ml	-----	0

n.d. = Not detected.
Note: Not detected values set to 1 to calculate mean and geometric mean.

7.3.2.7 Impairment of Designated Water Quality Beneficial Uses

Based on the State of North Dakota's impairment assessment methodology (Section 4.1.6.3), the water quality conditions monitored in Lake Audubon during 2002 and 2006 do not indicate any impairment of any designated water quality dependent beneficial uses.

7.3.3 WATER QUALITY TRENDS (1980 THROUGH 2006)

Water quality trends over the period of 1982 through 2006 were determined for Lake Yankton for Secchi depth, total phosphorus, chlorophyll *a*, and TSI (i.e., trophic status). The assessment was based on near-surface sampling of water quality conditions in the lake during the months of May through October at the deepwater site (i.e., site YAKLKND1). Plate 390 displays a scatter-plot of the collected data for the four parameters, a linear regression trend line, and the significance of the trend line (i.e., $\alpha = 0.05$). For the assessment period, Lake Yankton exhibited significant trends for Sechhi depth (decreasing) and TSI (increasing) (Plate 390). No significant trends were detected for total phosphorus and chlorophyll *a* (Plate 30). Over the 25-year period, the lake has generally remained in a moderately eutrophic to eutrophic state (Plate 390).

8 WATER QUALITY MONITORING AND MANAGEMENT ACTIVITIES PLANNED FOR FUTURE YEARS

8.1 WATER QUALITY DATA COLLECTION

A tentative schedule of water quality monitoring targeted for implementation over the next 5 years is given in Table 8.1. The identified data collection activities are considered the minimum needed to allow for the annual assessment of water quality conditions at District projects and the preparation of project-specific water quality reports and water quality management objectives for the Mainstem System Projects. The actual monitoring activities that are implemented will be dependent upon the availability of future resources.

8.2 PROJECT-SPECIFIC WATER QUALITY MANAGEMENT PLANNING

Corps guidance for water quality and environmental management at civil works projects (USACE, 1995) identifies the need to develop specific water quality management objectives for each project and to outline procedures to be implemented to meet those objectives. The identified objectives and procedures are to be included in the project water control plans. The water quality management objectives are to be reviewed and updated as needed, but at least every 10 years.

The Omaha District's intent is to develop water quality management objectives for Mainstem System project based on the findings presented in project-specific water quality reports. Therefore, it is important that the project-specific report for a project be updated prior to the development or update of the water quality management objectives for the project. This will ensure that the water quality management objectives for the projects address all of the known surface water quality issues and concerns. Where data are lacking or water quality issues need to be further evaluated, monitoring should be implemented to address these data needs prior to the preparation of the project-specific water quality report. Water quality management objectives will be developed in coordination with project operations staff and, as appropriate, the Northwestern Division's Missouri River Basin Water management Division (MRBWMD). The project water quality management objectives will be provided to the District's Engineering and Operation Divisions and the MRBWMD for incorporation into Project Water Control Manuals and Master Plans.

The CE-QUAL-W2 hydrodynamic and water quality model is being applied to facilitate the development of project-specific water quality reports and project-specific water quality management objectives. The tentative schedule for implementing these water-quality management planning activities on the Mainstem System projects is given in Table 8.2.

8.3 TOTAL MAXIMUM DAILY LOADS (TMDLS)

The District will participate, as appropriate, as a stakeholder in the development and implementation of TMDLs on waterbodies that involve District projects.

Table 8.1. Water quality monitoring planned by the District at Missouri River Mainstem System Projects the next 5 years and the intended data collection approach. Actual monitoring activities implemented will be dependent upon available resources.

Mainstem Project Areas to be Monitored	Long-Term Fixed Station Monitoring	Intensive Surveys	Special Studies	Investigative Monitoring
• Fort Peck		*	X[c]	X[e]
- Fort Peck Reservoir (3 Sites: Near-dam, Hell Creek, and Rock Creek)	X[a]			
- Missouri River Inflow to Fort Peck Reservoir (near Landusky, MT)	X[a]			
- Fort Peck Powerplant ("Raw-Water" Supply Line)	X[a]			
• Garrison		*	X[d]	X[e]
- Garrison Reservoir (4 Sites: Near-dam, Beulah Bay, Deepwater Bay, New Town)	X[a]			
- Missouri River Inflow to Garrison Reservoir (near Williston, ND)	X[a]			
- Garrison Powerplant ("Raw-Water" Supply Line)	X[a]			
- Lake Audubon	2009 2012			
• Oahe				X[e]
- Oahe Reservoir (4 Sites: Near-dam, Cheyenne River Area, Whitlocks Bay, and Mobridge)	X[a]			
- Missouri River Inflow to Oahe Reservoir (near Bismarck, ND)	X[a]			
- Oahe Powerplant ("Raw-Water" Supply Line)	X[a]			
- Lake Pocasse	2009 2012			
• Big Bend				
- Big Bend Reservoir (1 Site: Near-dam)	X[a]			
- Big Bend Reservoir (4 Sites: North Bend Area, Iron Nation Area, Cedar Creek, and Antelope Creek)		2008-2010		
- Bad River Inflow to Big Bend Reservoir (at Fort Pierre, SD)		2008-2010		
- Big Bend Powerplant ("Raw-Water" Supply Line)	X[a]			
• Fort Randall				X[e]
- Fort Randall Reservoir (1 Site: Near-dam)	X[a]			
- Fort Randall Reservoir (6 Sites: Pease Creek, Platte Creek, Snake Creek, Elm Creek, White River, Chamberlain)		2006-2008		
- White River Inflow to Fort Randall Reservoir (near Oacoma, SD)		2006-2008		
- Fort Randall Powerplant ("Raw-Water" Supply Line)	X[a]			
• Gavins Point	X[a]			X[e]
- Gavins Point Reservoir (1 Site: Near-dam)	X[a]			
- Gavins Point Reservoir (4 Sites: Weigand, Bloomfield, Devils Nest, and Charley Creek)		2008-2010		
- Niobrara River Inflow to Missouri River (near Niobrara, NE)		2008-2010		
- Gavins Point Powerplant ("Raw-Water" Supply Line)	X[a]			
- Lake Yankton	2009 2012			

Table 8.1. (Continued)

• Missouri River – Fort Randall Dam to Gavins Point Reservoir (3 Sites: Fort Randall Dam Tailwaters, RM851, and RM841)	X[b]			X[e]
• Missouri River – Gavins Point Dam to Rulo, Nebraska (7 Sites: Gavins Point Tailwaters, RM774, RM753, RM691, RM619, RM563, and RM498).	X[b]	2010-2012[f]		X[e]

* A 3-year intensive survey was completed at Garrison in 2005, Fort Peck in 2006, Oahe in 2007, and Fort Randall in 2008.

[a] To be monitored every year.

[b] Six sites (RM851, RM774, RM691, RM619, RM563, and RM498) are being monitored under an Interagency Support Agreement with the Nebraska Department of Environmental Quality.

[c] Special Study will be implemented, as necessary, to facilitate application of a Scoping Study to evaluate the feasibility of constructing a "multi-level" intake structure at Fort Peck Dam to allow better management of the water temperature of water discharged through the Fort Peck powerplant.

[d] Special Study will be implemented, as necessary, to facilitate application of short-term water quality measures at Garrison Dam for the management of coldwater fishery habitat in Garrison Reservoir.

[e] Investigative Monitoring will be conducted as necessary and appropriate.

[f] Joint intensive survey will be pursued with the Kansas City District to monitoring water quality along the Missouri River from Gavins Point Dam to the river's mouth at St. Louis, MO.

Table 8.2. Tentative schedule for water quality management planning activities for the Mainstem System Projects.

Planning Activity	Fort Peck	Garrison	Oahe	Big Bend	Fort Randall	Gavins Point	Missouri River*
Ambient water quality monitoring	Ongoing	Ongoing	Ongoing	Ongoing	Ongoing	Ongoing	Ongoing
Conduct 3-year intensive water quality survey	Completed (2006)	Completed (2005)	Completed (2007)	2008-10	Completed (2008)	2008-10	2010-12
Prepare Water Quality Special Study Report (Findings of the 3-year intensive water quality survey)	Completed (2007)	Completed (2006)	Completed (2008)	2011	Completed (2009)	2011	2013
Application of CE-QUAL-W2 hydrodynamic and water quality model	2009	Completed (2008)	2010/2011	2015	2011/12	2014	2012/2013
Prepare Water Quality Special Study Report (Application of the CE-QUAL-W2 Model)	2009	2008	2011	2015	2012	2014	2013
Prepare Project-Specific Water Quality Report	2011	2010	2012	2016	2013	2015	2014
Develop project-specific water quality management objectives	2011	2010	2012	2016	2013	2015	2014

* Downstream of Gavins Point Dam.

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10 PLATES

Plate 1. Summary of monthly (May through September) water quality conditions monitored in Fort Peck Reservoir near Fort Peck Dam (Site FTPLK1772A) during the 5-year period 2004 through 2008.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0 1	25	2203 2	2202.6	2198.7	2210.0	-----	-----	-----
Water Temperature (C)	0 1	1,264	12.6	12.1	1.0	25.5	26.7[1,2]	0	0%
Dissolved Oxygen (mg/l)	0 1	1,264	8.8	8.8	5.0	12.2	5.0[1,3]	0	0%
Dissolved Oxygen (% Sat.)	0 1	1,220	85 9	89.7	48.7	107.4	-----	-----	-----
Specific Conductance (umho/cm)	1	1,220	510	529	364	556	-----	-----	-----
pH (S.U.)	0 1	1,172	8 2	8.2	7.5	8.7	6.5[1,3], 9.0[1,2]	0	0%
Turbidity (NTUs)	1	1,168	5	2	n.d.	33	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	1,220	370	353	279	526	-----	-----	-----
Secchi Depth (in.)	1	25	133	140	56	216	-----	-----	-----
Alkalinity, Total (mg/l)	7	55	156	154	134	180	-----	-----	-----
Ammonia, Total (mg/l)	0.02	57	-----	0.03	n.d.	0.58	3.9 [1,2,4], 1.7[1,4,5]	0	0%
Carbon, Total Organic (mg/l)	0.05	53	2.4	2.4	n.d.	3.8	-----	-----	-----
Chemical Oxygen Demand, Total (mg/l)	2	34	7	7	n.d.	17	-----	-----	-----
Chloride (mg/l)	1	32	8	8	7	9	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	911	-----	n.d.	n.d.	8	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	25	-----	1	n.d.	4	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	43	347	340	260	426	-----	-----	-----
Kjeldahl N, Total (mg/l)	0 1	57	0 3	0.2	n.d.	1.4	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	57	-----	n.d.	n.d.	0.15	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	57	-----	0.02	n.d.	0.11	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	57	0.07	0.04	n.d.	0.66	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	57	-----	n.d.	n.d.	0.03	-----	-----	-----
Sulfate (mg/l)	1	53	119	120	37	130	-----	-----	-----
Suspended Solids, Total (mg/l)	4	57	-----	n.d.	n.d.	14	-----	-----	-----
Iron, Total (ug/l)	40	35	126	70	n.d.	1,372	-----	-----	-----
Manganese, Total (ug/l)	2	35	6	4	n.d.	40			
Microcystin, Total (ug/l)	0.2	19	-----	n.d.	n.d.	0.3	-----	-----	-----

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for B-3 classified waters.
- (2) Daily maximum criterion (monitoring results directly comparable to criterion).
- (3) Daily minimum criterion (monitoring results directly comparable to criterion).
- (4) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (5) 30-day average criterion (monitoring results not directly comparable to criterion).

Plate 2. Summary of monthly (June through September) water quality conditions monitored in Fort Peck Reservoir near Skunk Coulee Bay (site FTPLK1778DW) during the 3-year period 2004 through 2006.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	12	2203.0	2202.9	2199 9	2206.2	-----	-----	-----
Water Temperature (C)	0.1	498	15.0	14.6	8 5	26.3	26.7[1,2]	0	0%
Dissolved Oxygen (mg/l)	0.1	468	8.3	8.4	5.7	10.0	5.0[1,3]	0	0%
Dissolved Oxygen (% Sat.)	0.1	468	86.5	90.9	57.1	106.5	-----	-----	-----
Specific Conductance (umho/cm)	1	468	497	493	422	545	-----	-----	-----
pH (S.U.)	0.1	430	8.2	8.3	7.4	8.7	6.5[1,3], 9.0[1,2]	0	0%
Turbidity (NTUs)	1	468	5.7	2.5	0.1	27.9	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	468	381	361	284	534	-----	-----	-----
Secchi Depth (in)	1	12	148	132	102	250	-----	-----	-----

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements.
(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.
(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).
(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.
(1) Criteria for B-3 classified waters.
(2) Daily maximum criterion (monitoring results directly comparable to criterion).
(3) Daily minimum criterion (monitoring results directly comparable to criterion).

Plate 3. Summary of monthly (June through September) water quality conditions monitored in Fort Peck Reservoir near The Pines Recreation Area (site FTPLK1789DW) during the 3-year period 2004 through 2006.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	12	2203.0	2202.9	2199.9	2206.2	-----	-----	-----
Water Temperature (C)	0.1	413	15.4	15.0	8.9	24.4	26.7[1,2]	0	0%
Dissolved Oxygen (mg/l)	0.1	413	8.0	8.3	2.2	9.7	5.0[1,3]	13	3%
Dissolved Oxygen (% Sat.)	0.1	413	83.7	89.0	20.7	107.1	-----	-----	-----
Specific Conductance (umho/cm)	1	413	494	490	416	559	-----	-----	-----
pH (S.U.)	0.1	379	8.2	8.3	6.9	8.8	6.5[1,3], 9.0[1,2]	0	0%
Turbidity (NTUs)	1	412	6.8	3.3	0.1	40.3	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	413	370	344	136	528	-----	-----	-----
Secchi Depth (in)	1	12	118	114	78	156	-----	-----	-----
Alkalinity, Total (mg/l)	7	30	158	160	140	174	-----	-----	-----
Ammonia N, Total (mg/l)	0.02	30	-----	0.04	n.d.	0.23	3.2 [1,2,4], 1.5[1,4,5]	0	0%
Carbon, Total Organic (mg/l)	0.05	30	2.4	2.4	2.2	2.8	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	8	7	6	4	12	-----	-----	-----
Chloride (mg/l)	1	8	8	8	7	8	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab	1	12	-----	1	n.d.	4	-----	-----	-----
Chlorophyll *a* (ug/l) – Field	1	412	-----	n.d.	n.d.	7.2	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	30	348	345	297	478	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	30	0.3	0.2	0.2	0.5	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	30	-----	n.d.	n.d.	0.57	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	30	0.05	0.04	n.d.	0.23	-----	-----	-----
Phosphorus, Total Dissolved (mg/l)	0.02	30	-----	0.02	n.d.	0.06	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	30	-----	n.d.	n.d.	0.05	-----	-----	-----
Sulfate (mg/l)	1	30	119	120	104	130	-----	-----	-----
Suspended Solids, Total (mg/l)	4	30	-----	n.d.	n.d.	10.0	-----	-----	-----
Microcystin (ug/l)	0.2	7	-----	n.d.	n.d.	n.d.	-----	-----	-----

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e , log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

(1) Criteria for B-3 classified waters.

(2) Daily maximum criterion (monitoring results directly comparable to criterion).

(3) Daily minimum criterion (monitoring results directly comparable to criterion).

(4) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

(5) 30-day average criterion (monitoring results not directly comparable to criterion).

Plate 4. Summary of monthly (June through September) water quality conditions monitored in Fort Peck Reservoir near Hell Creek Bay (site FTPLK1805DW) during the 5-year period 2004 through 2008.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	17	2203.3	2202.6	2198.7	2210.0	-----	-----	-----
Water Temperature (C)	0.1	409	16.2	16.7	5.5	27.4	26.7[1,2]	1	<1%
Dissolved Oxygen (mg/l)	0.1	409	8.1	8.5	3.5	12.1	5.0[1,3]	31	8%
Dissolved Oxygen (% Sat.)	0.1	389	84.7	90.2	35.3	111.6	-----	-----	-----
Specific Conductance (umho/cm)	1	389	505	517	413	565	-----	-----	-----
pH (S.U.)	0.1	365	8.3	8.4	7.3	9.0	6.5[1,3], 9.0[1,2]	0	0%
Turbidity (NTUs)	1	365	6	4	n.d.	31	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	389	345	328	263	508	-----	-----	-----
Secchi Depth (in)	1	17	87	84	46	144	-----	-----	-----
Alkalinity, Total (mg/l)	7	36	153	150	140	170	-----	-----	-----
Ammonia N, Total (mg/l)	0.02	36	-----	0.03	n.d.	0.21	3 9 [1,2,4], 1.7[1,4,5]	0	0%
Carbon, Total Organic (mg/l)	0.05	34	2.6	2.6	n.d.	4.5	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	17	9	9	3	18	-----	-----	-----
Chloride (mg/l)	1	22	8	8	7	9	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab	1	17	4	3	1	10	-----	-----	-----
Chlorophyll *a* (ug/l) – Field	1	291	-----	1	n.d.	13	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	36	344	344	294	422	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	36	0.3	0.3	n.d.	0.6	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	36	-----	n.d.	n.d.	0.14	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	36	0.05	0.03	n.d.	0 34	-----	-----	-----
Phosphorus, Total Dissolved (mg/l)	0.02	36	-----	0.02	n.d.	0.24	-----	-----	-----
Orthophosphorus, Dissolved (mg/l)	0.02	36	-----	n.d.	n.d.	0.23	-----	-----	-----
Sulfate (mg/l)	1	36	115	120	85	140	-----	-----	-----
Suspended Solids, Total (mg/l)	4	36	-----	n.d.	n.d.	12	-----	-----	-----
Iron, Total (ug/l)	40	21	277	147	20	2,721			
Manganese, Total (ug/l)	2	21	9	6	n.d.	30			
Microcystin (ug/l)	0.2	13	-----	n.d.	n.d.	0.3	-----	-----	-----

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

(1) Criteria for B-3 classified waters.

(2) Daily maximum criterion (monitoring results directly comparable to criterion).

(3) Daily minimum criterion (monitoring results directly comparable to criterion).

(4) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

(5) 30-day average criterion (monitoring results not directly comparable to criterion).

Plate 5. Summary of monthly (June through September) water quality conditions monitored in Fort Peck Reservoir in the Big Dry Creek Arm of the reservoir (site FTPLKBDCA01) during the 3-year period 2004 through 2006.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	12	2203.0	2202.9	2199.9	2206.2	-----	-----	-----
Water Temperature (C)	0.1	471	15.0	14.5	8.7	25.4	26.7[1,2]	0	0%
Dissolved Oxygen (mg/l)	0.1	471	8.4	8.4	5.6	10.0	5.0[1,3]	0	0%
Dissolved Oxygen (% Sat.)	0.1	471	86.9	91.1	55.1	110.6	-----	-----	-----
Specific Conductance (umho/cm)	1	470	501	496	350	550	-----	-----	-----
pH (S.U.)	0.1	471	8.3	8.3	7.6	9.0	6.5[1,3], 9.0[1,2]	0	0%
Turbidity (NTUs)	1	471	6.0	2.4	0.1	45.1	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	471	382	363	301	507	-----	-----	-----
Secchi Depth (in)	1	12	152	159	76	240	-----	-----	-----

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements.
(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.
(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e , log conversion of logarithmic pH values was not done to calculate mean).
(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.
(1) Criteria for B-3 classified waters.
(2) Daily maximum criterion (monitoring results directly comparable to criterion).
(3) Daily minimum criterion (monitoring results directly comparable to criterion).

Plate 6. Summary of monthly (June through September) water quality conditions monitored in Fort Peck Reservoir near Rock Creek Bay (site FTPLKBDCA02) during the 5-year period 2004 through 200**8.**

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	17	2203.8	2203.1	2198.7	2210.0	-----	-----	-----
Water Temperature (C)	0.1	361	17.3	17.4	5.2	24.2	26.7[1,2]	0	0%
Dissolved Oxygen (mg/l)	0.1	361	12.6	8.5	5.6	11.7	5.0[1,3]	0	0%
Dissolved Oxygen (% Sat.)	0.1	347	92.9	94.8	59.9	103.0	-----	-----	-----
Specific Conductance (umho/cm)	1	347	529	544	433	580	-----	-----	-----
pH (S.U.)	0.1	347	8.5	8.5	7.9		6.5[1,3], 9.0[1,2]	0	0%
Turbidity (NTUs)	1	295	5	3	n.d.	25	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	347	353	339	273	492	-----	-----	-----
Secchi Depth (in)	1	17	109	102	54	172	-----	-----	-----
Alkalinity, Total (mg/l)	7	31	156	157	140	179	-----	-----	-----
Ammonia N, Total (mg/l)	0.02	31	-----	0.03	n.d.	0 25	3.9 [1,2,4], 1.7[1,4,5]	0	0%
Carbon, Total Organic (mg/l)	0.05	30	2.5	2.5	n.d.	4.0	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	17	7	8	n.d.	14	-----	-----	-----
Chloride (mg/l)	1	17	8	8	7	9	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab	1	19	-----	1	n.d.	7	-----	-----	-----
Chlorophyll *a* (ug/l) – Field	1	274	-----	1	n.d.	5	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	31	366	360	315	479	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	31	0.3	0.3	n.d.	0.8	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	31	-----	n.d.	n.d.	0.46	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	30	-----	0.03	n.d.	0.13	-----	-----	-----
Phosphorus, Total Dissolved (mg/l)	0.02	31	-----	n.d.	n.d.	0.08	-----	-----	-----
Orthophosphorus, Dissolved (mg/l)	0.02	31	-----	n.d.	n.d.	0.04	-----	-----	-----
Sulfate (mg/l)	1	31	128	126	110	180	-----	-----	-----
Suspended Solids, Total (mg/l)	4	31	-----	n.d.	n.d.	10	-----	-----	-----
Iron, Total (ug/l)	40	15	128	100	n.d.	277	-----	-----	-----
Manganese, Total (ug/l)	2	15	6	6	2	13	-----	-----	-----
Microcystin (ug/l)	0.2	14	-----	n.d.	n.d.	0.9	-----	-----	-----

n.d. = Not detected.

[A] Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

[B] Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

[C] Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e , log conversion of logarithmic pH values was not done to calculate mean).

[D] Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- [1] Criteria for B-3 classified waters.
- [2] Daily maximum criterion (monitoring results directly comparable to criterion).
- [3] Daily minimum criterion (monitoring results directly comparable to criterion).
- [4] Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- [5] 30-day average criterion (monitoring results not directly comparable to criterion).

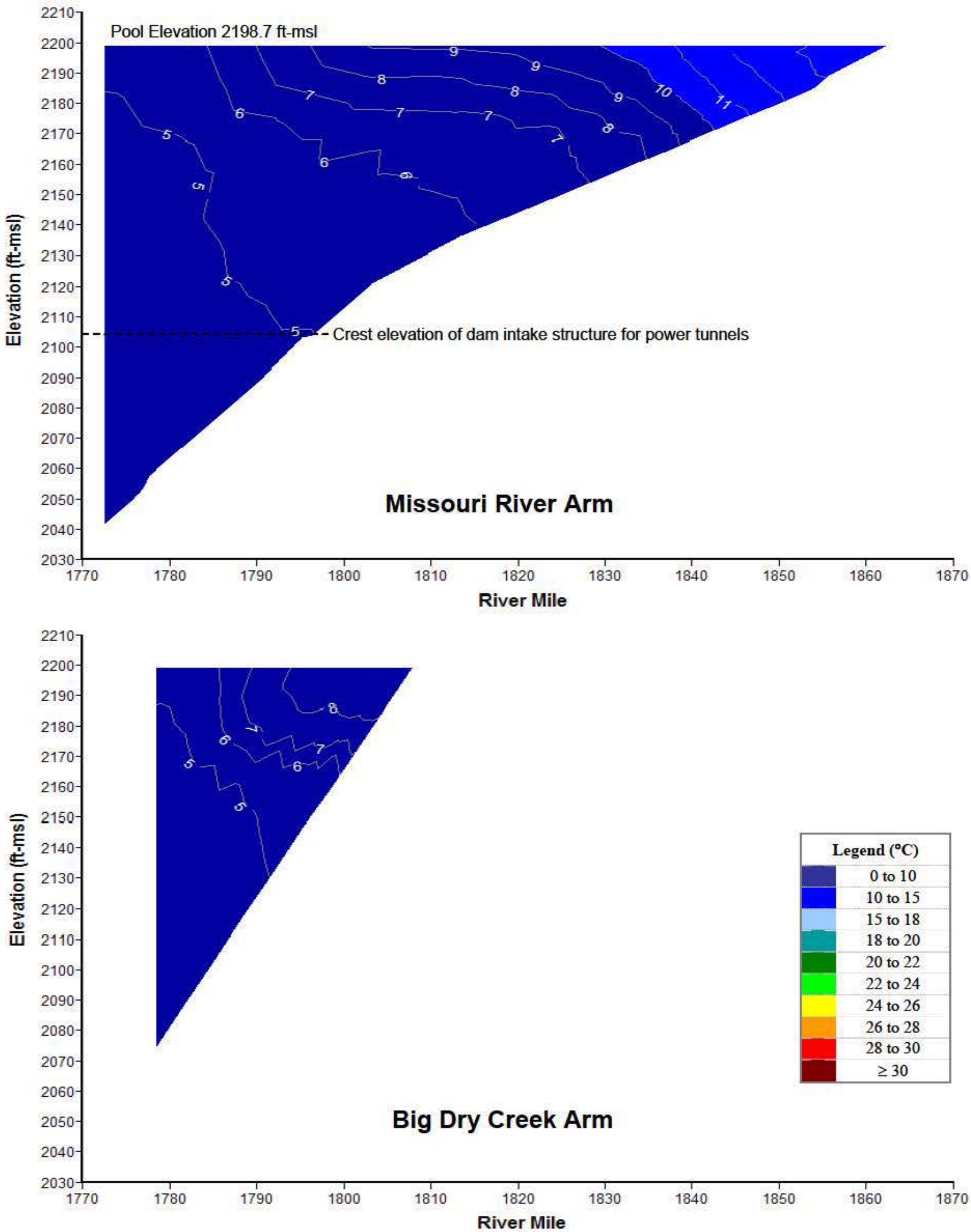


Plate 7. Longitudinal water temperature (°C) contour plot of Fort Peck Reservoir based on depth-profile water temperatures measured at sites FTPLK1772A, FTPLK1805DW, FTPLKBDCA02, and FTPNFMORR1 on May 7, 2008.

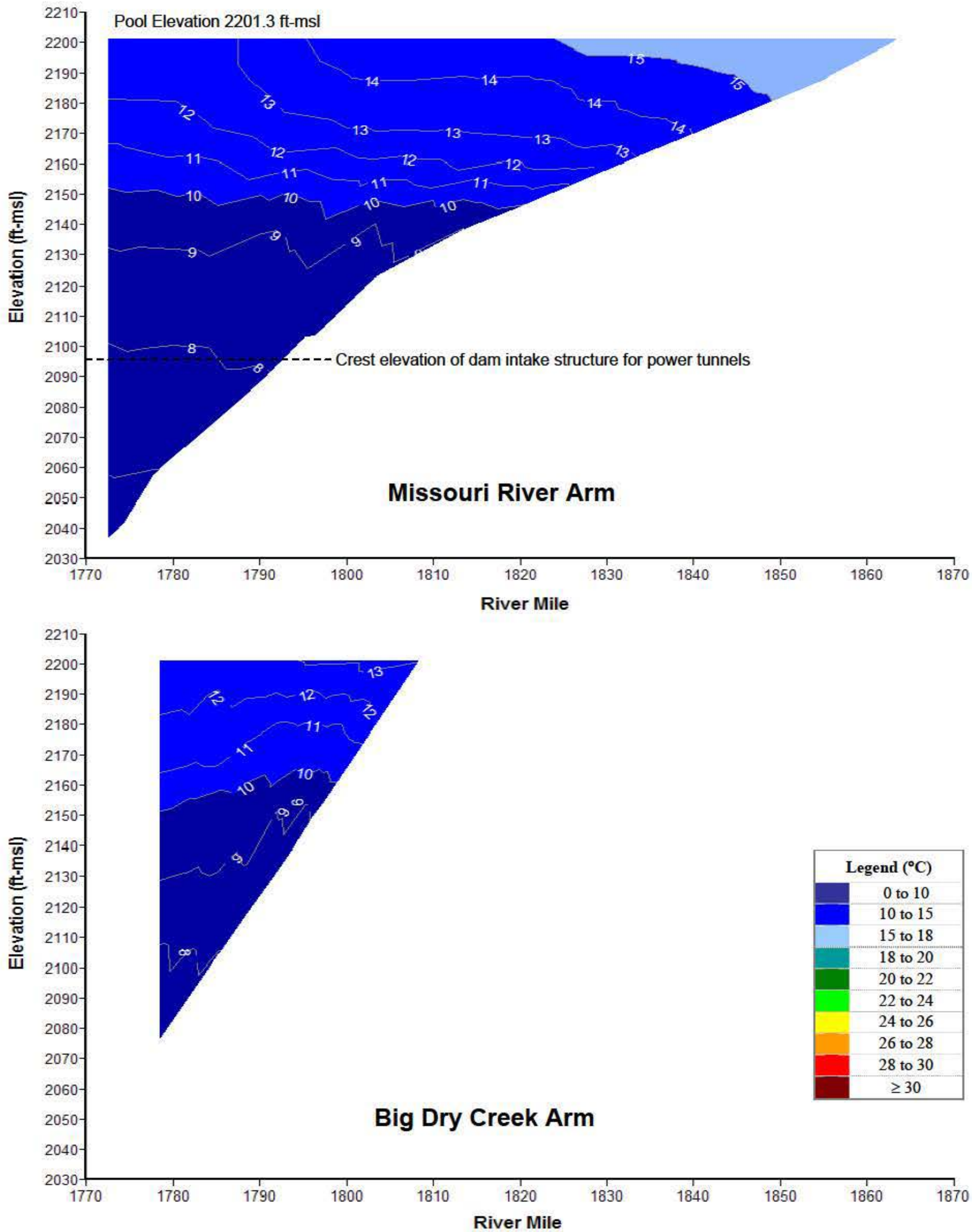


Plate 8. Longitudinal water temperature (°C) contour plot of Fort Peck Reservoir based on depth-profile water temperatures measured at sites FTPLK1772A, FTPLK1805DW, FTPLKBDCA02, and FTPNFMORR1 on June 4, 2008.

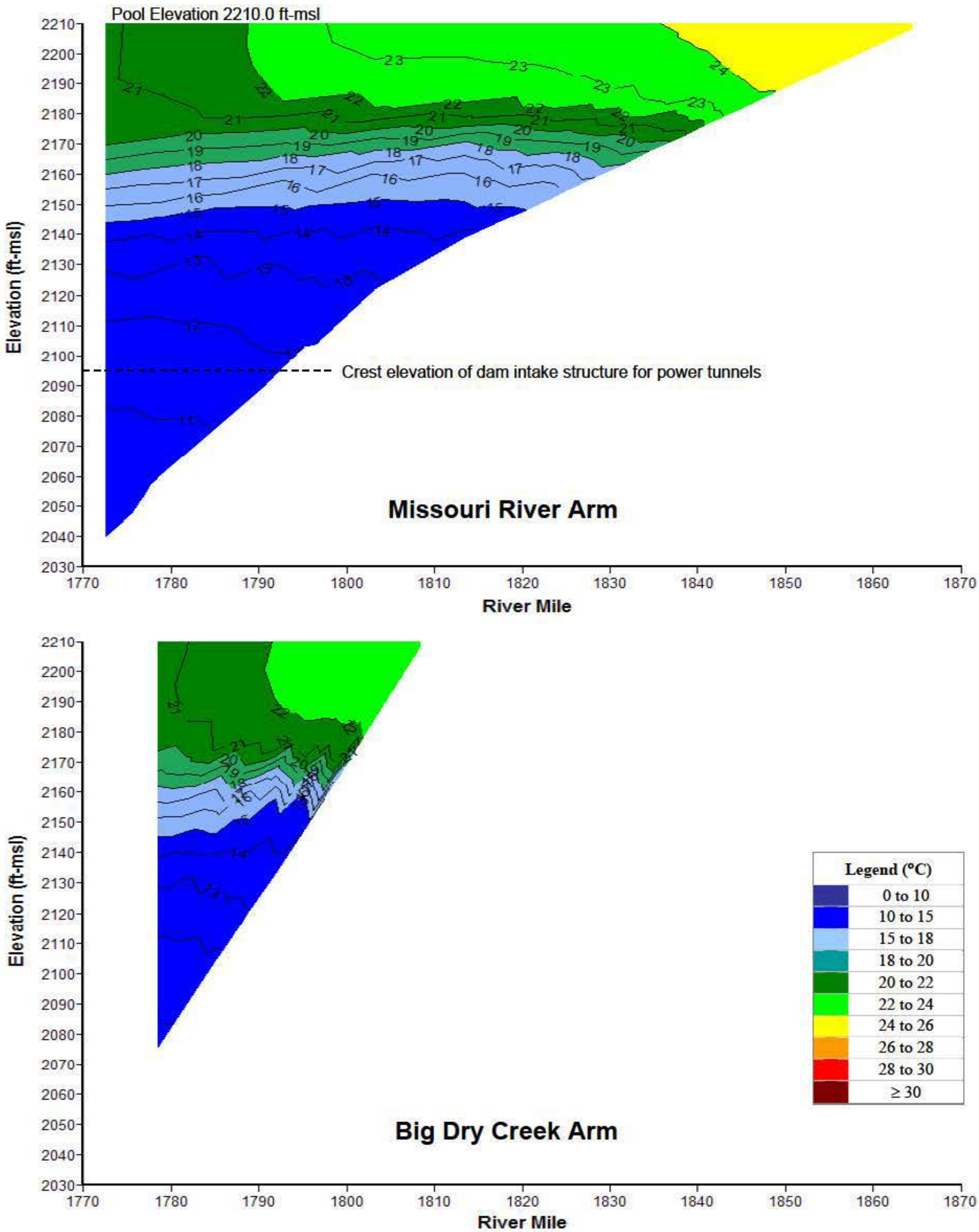


Plate 9. Longitudinal water temperature (°C) contour plot of Fort Peck Reservoir based on depth-profile water temperatures measured at sites FTPLK1772A, FTPLK1805DW, FTPLKBDCA02, and FTPNFMORR1 on August 6, 2008.

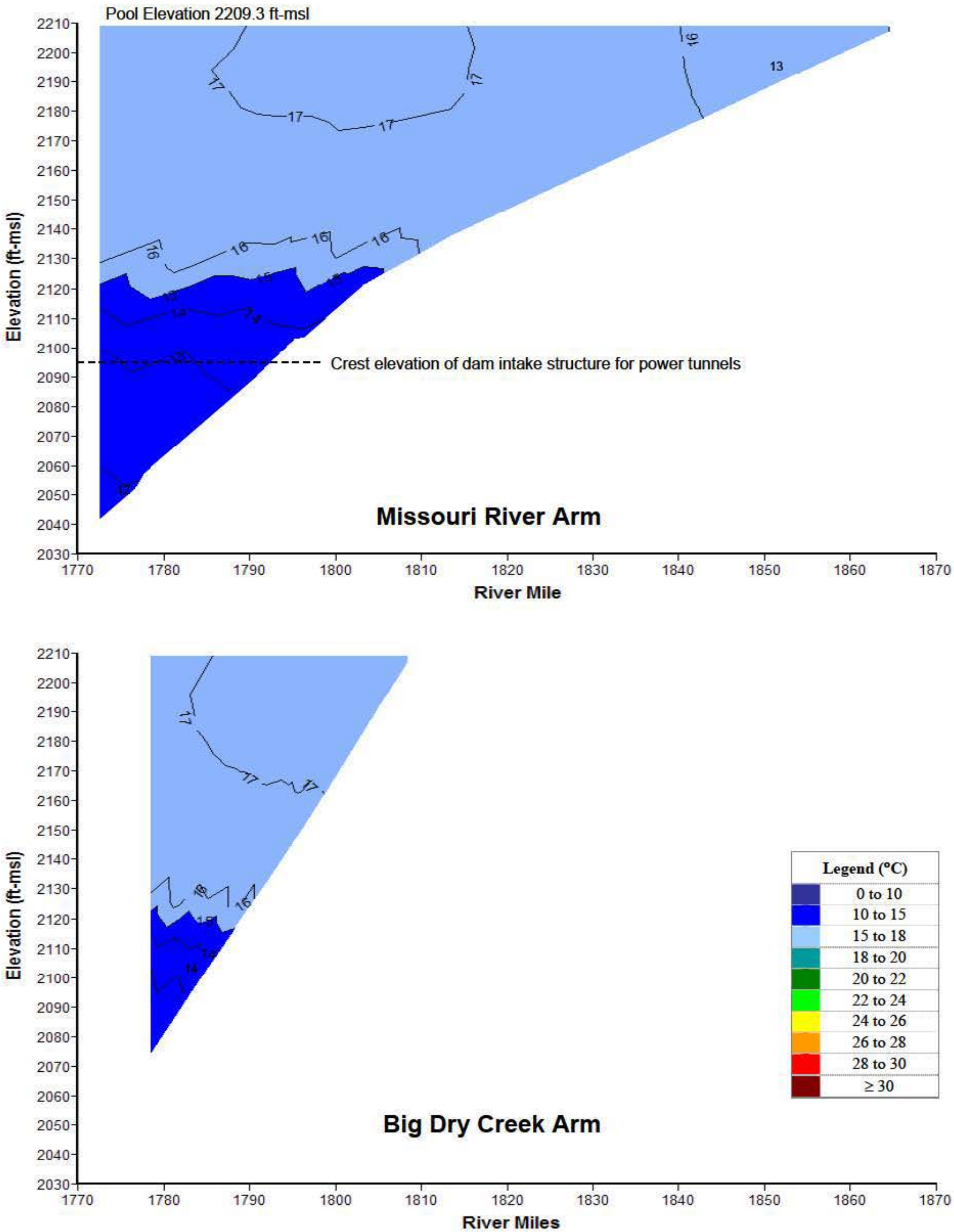


Plate 10. Longitudinal water temperature (°C) contour plot of Fort Peck Reservoir based on depth-profile water temperatures measured at sites FTPLK1772A, FTPLK1805DW, FTPLKBDCA02, and FTPNFMORR1 on September 8, 2008.

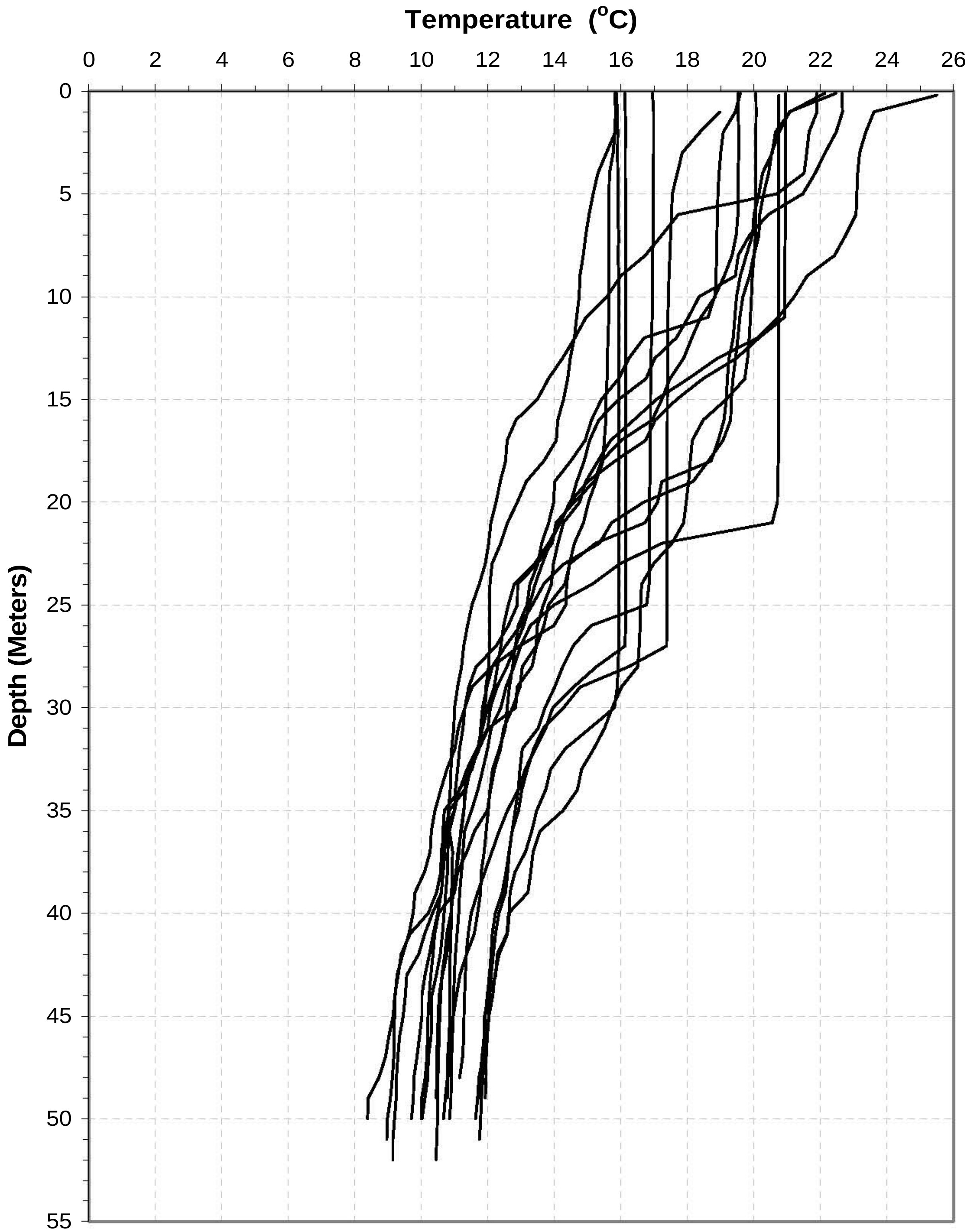


Plate 11. Temperature depth profiles for Fort Peck Reservoir compiled from data collected at the near-dam, deepwater ambient monitoring site (i.e., FTPLK1772A) during the summer over the 5-year period of 2004 to 2008.

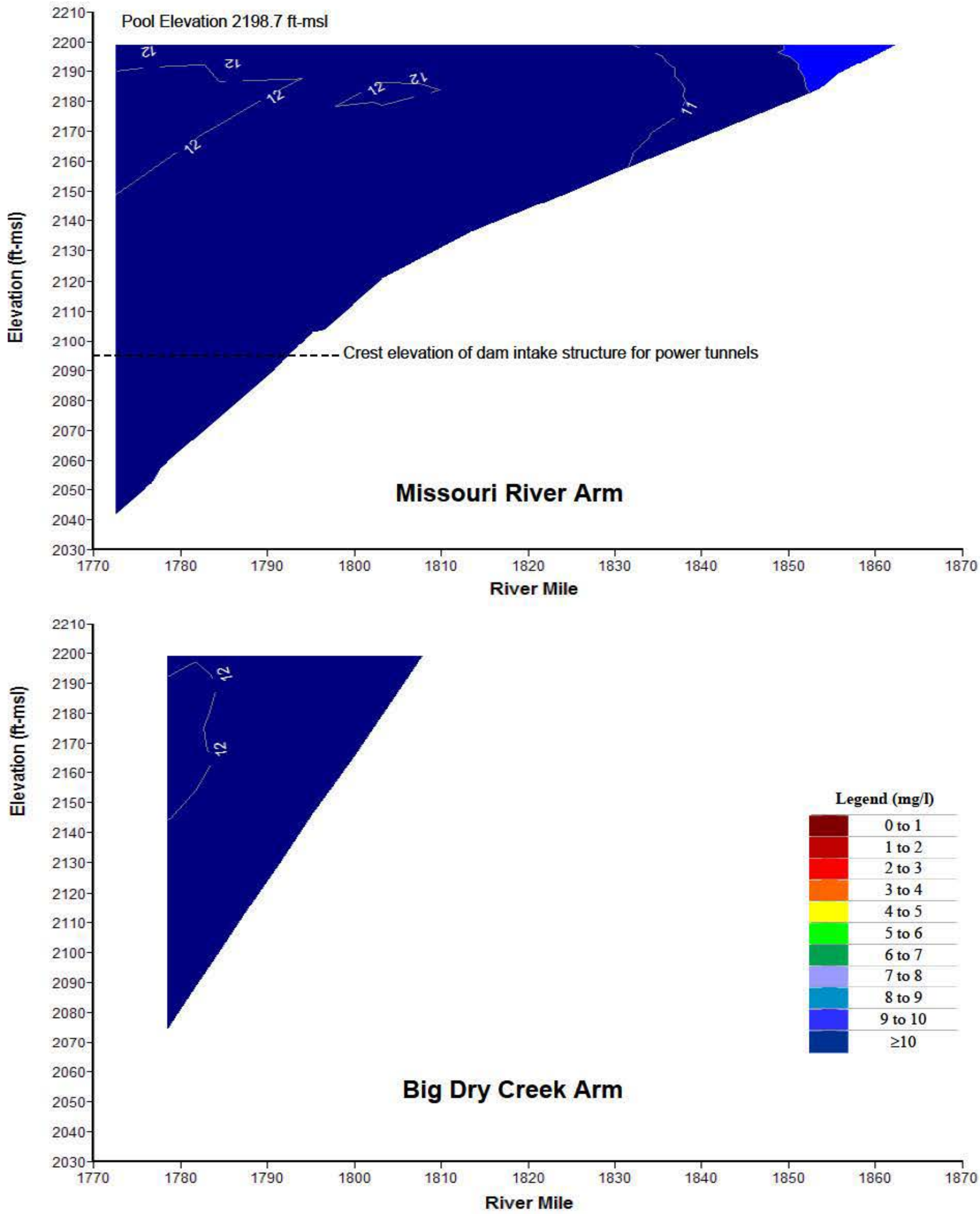


Plate 12. Longitudinal dissolved oxygen (mg/l) contour plot of Fort Peck Reservoir based on depth-profile dissolved oxygen concentrations monitored at sites FTPLK1772A, FTPLK1805DW, FTPLKBDCA02, and FTPNFMORR1 on May 7, 2008.

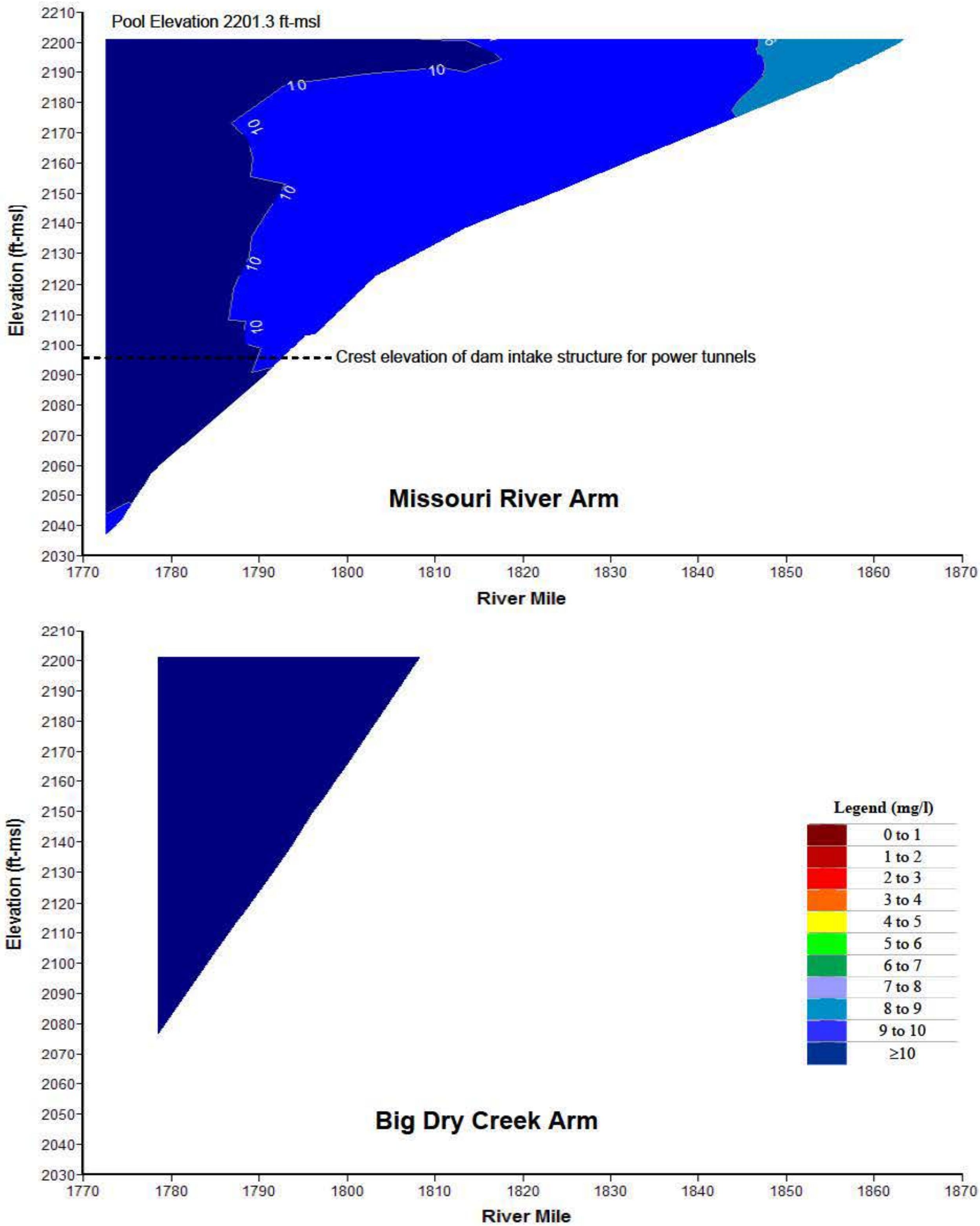
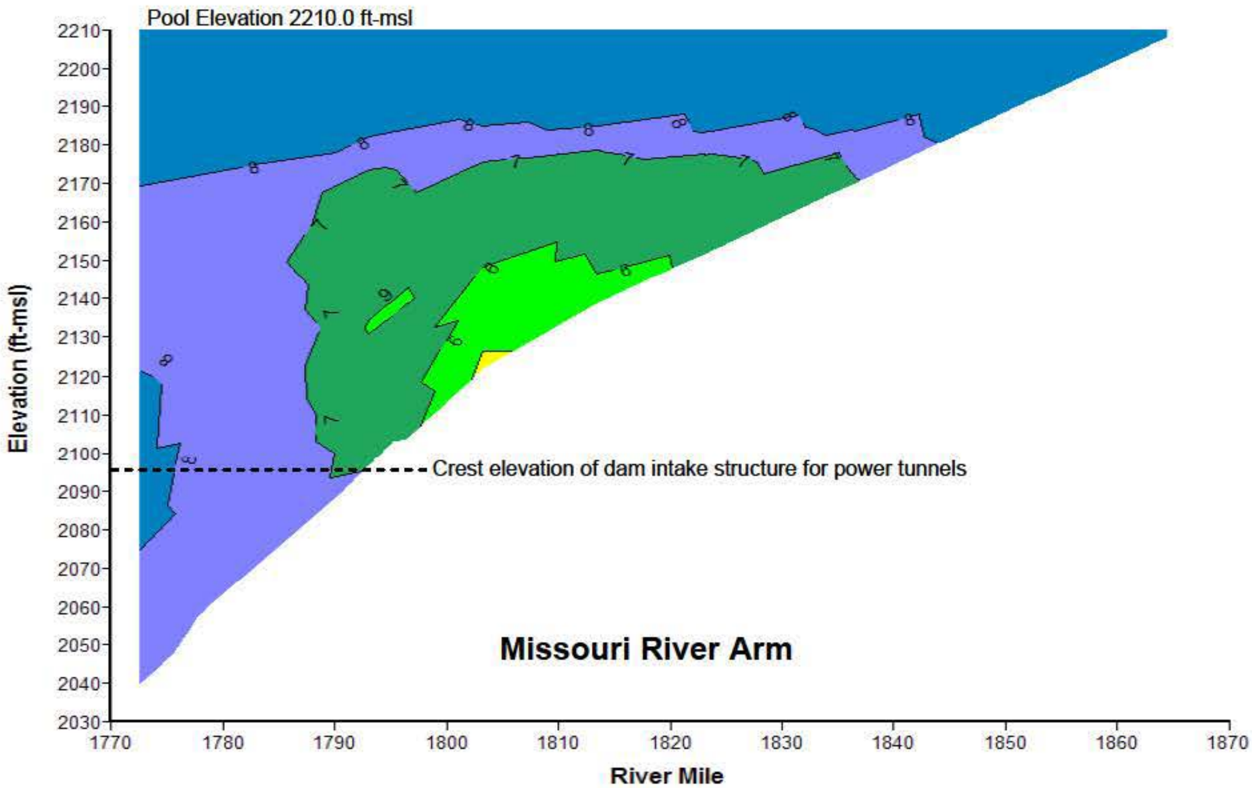


Plate 13. Longitudinal dissolved oxygen (mg/l) contour plot of Fort Peck Reservoir based on depth-profile dissolved oxygen concentrations monitored at sites FTPLK1772A, FTPLK1805DW, FTPLKBDCA02, and FTPNFMORR1 on June 4, 2008.



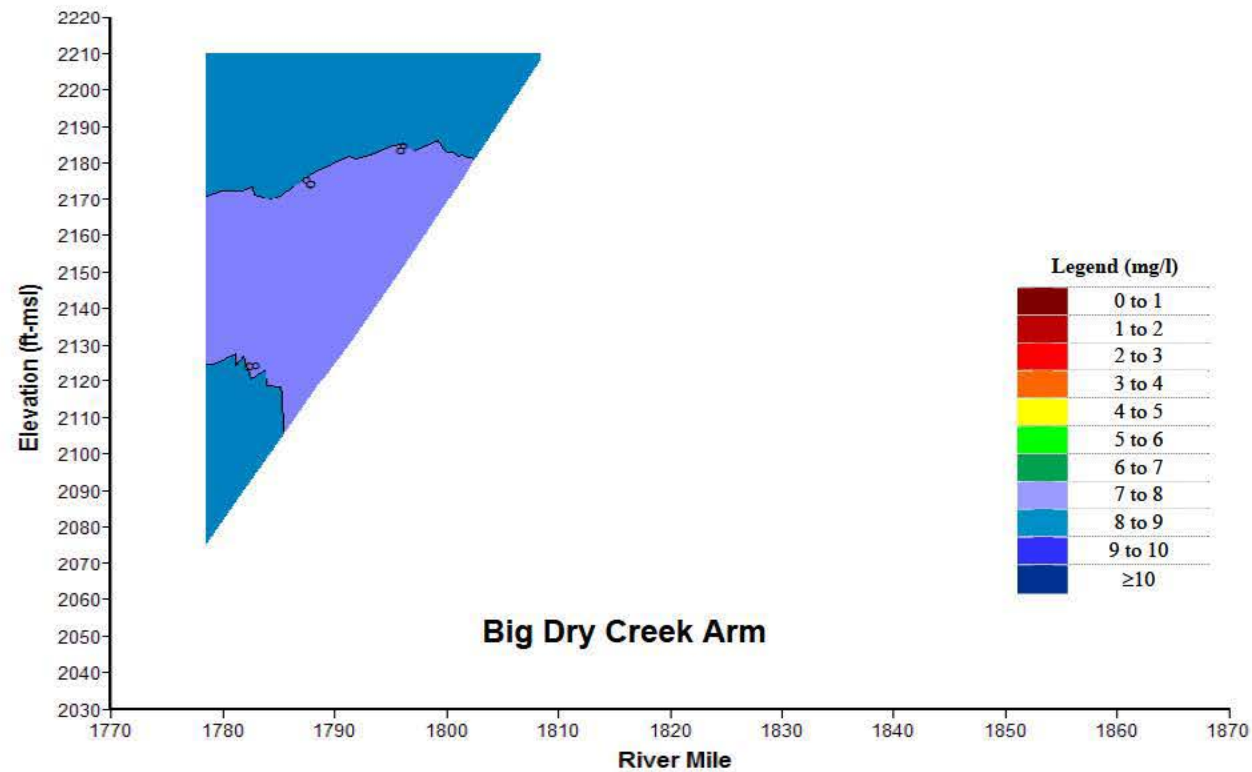


Plate 14. Longitudinal dissolved oxygen (mg/l) contour plot of Fort Peck Reservoir based on depth-profile dissolved oxygen concentrations monitored at sites FTPLK1772A, FTPLK1805DW, FTPLKBDCA02, and FTPNFMORR1 on August 6, 2008.

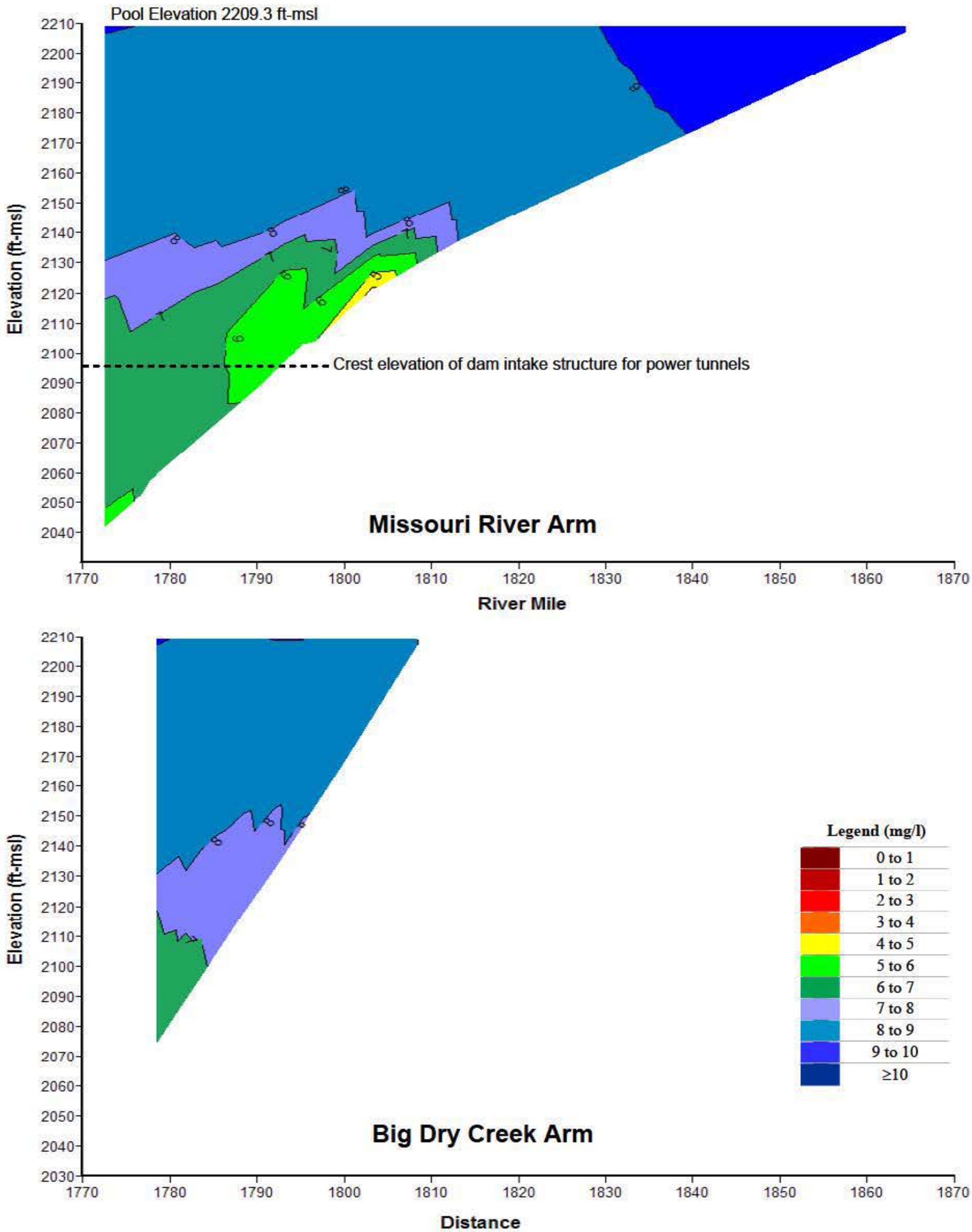


Plate 15. Longitudinal dissolved oxygen (mg/l) contour plot of Fort Peck Reservoir based on depth-profile dissolved oxygen concentrations monitored at sites FTPLK1772A, FTPLK1805DW, FTPLKBDCA02, and FTPNFMORR1 on September 8, 2008.

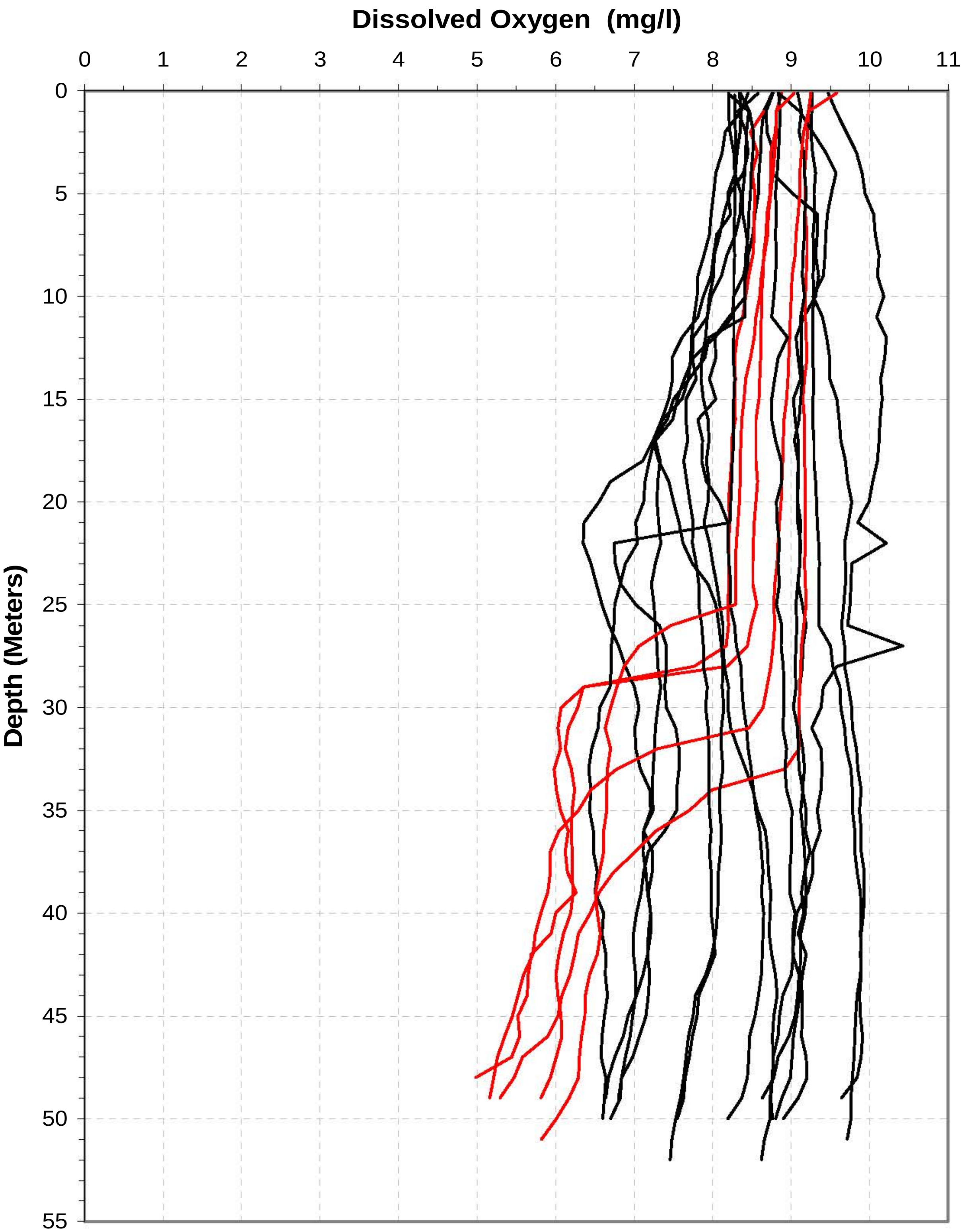


Plate 16. Dissolved oxygen depth profiles for Fort Peck Reservoir compiled from data collected at the near-dam, deepwater ambient monitoring site (i.e., FTPLK1772A) during the summer over the 5-year period of 2004 to 2008.
(Note: Red profile plots were measured in the month of September.)

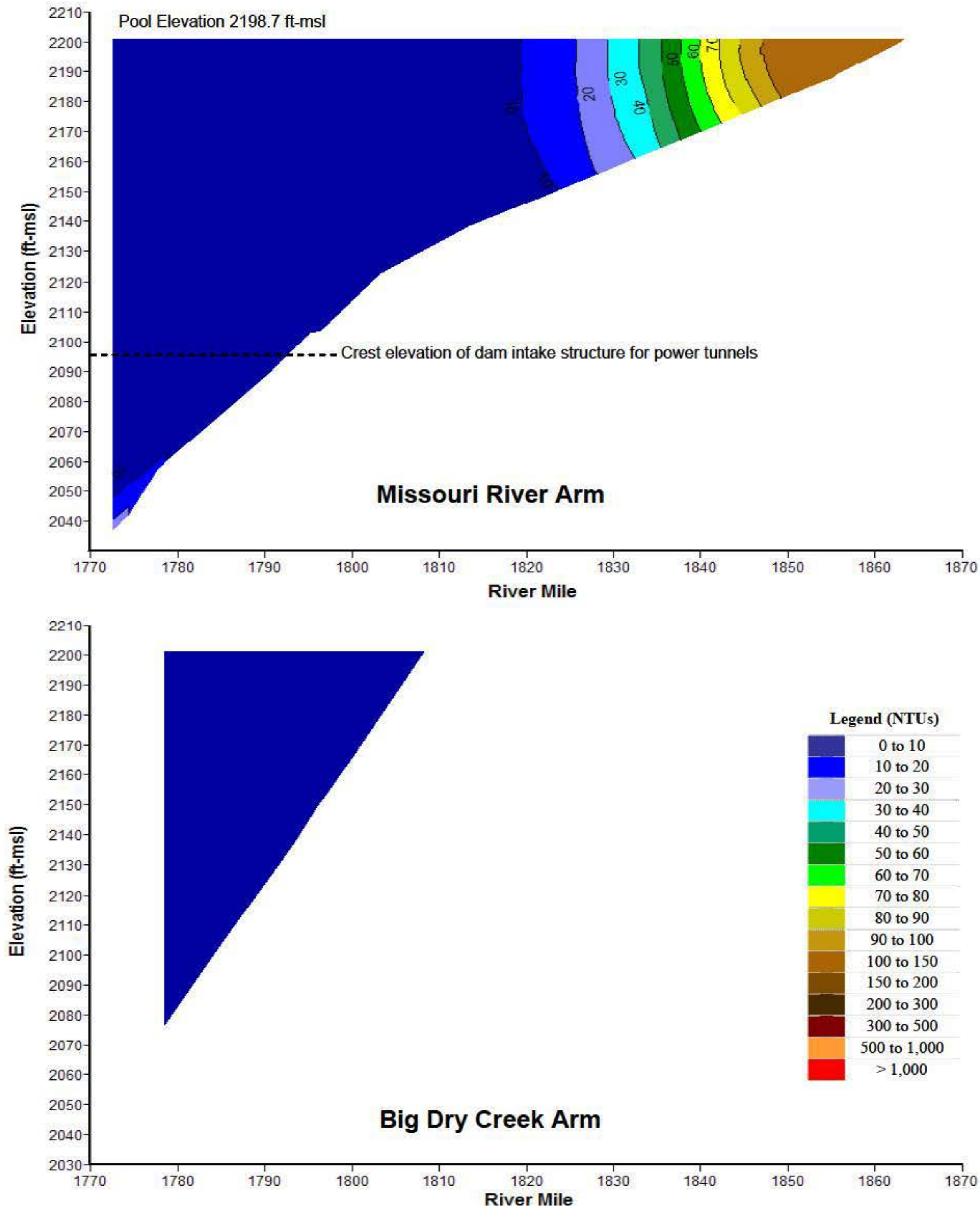


Plate 17. Longitudinal turbidity (NTU) contour plot of Fort Peck Reservoir based on depth-profile turbidity levels monitored at sites FTPLK1772A, FTPLK1805DW, FTPLKBDCA02, and FTPNFMORR1 on June 4, 2008.

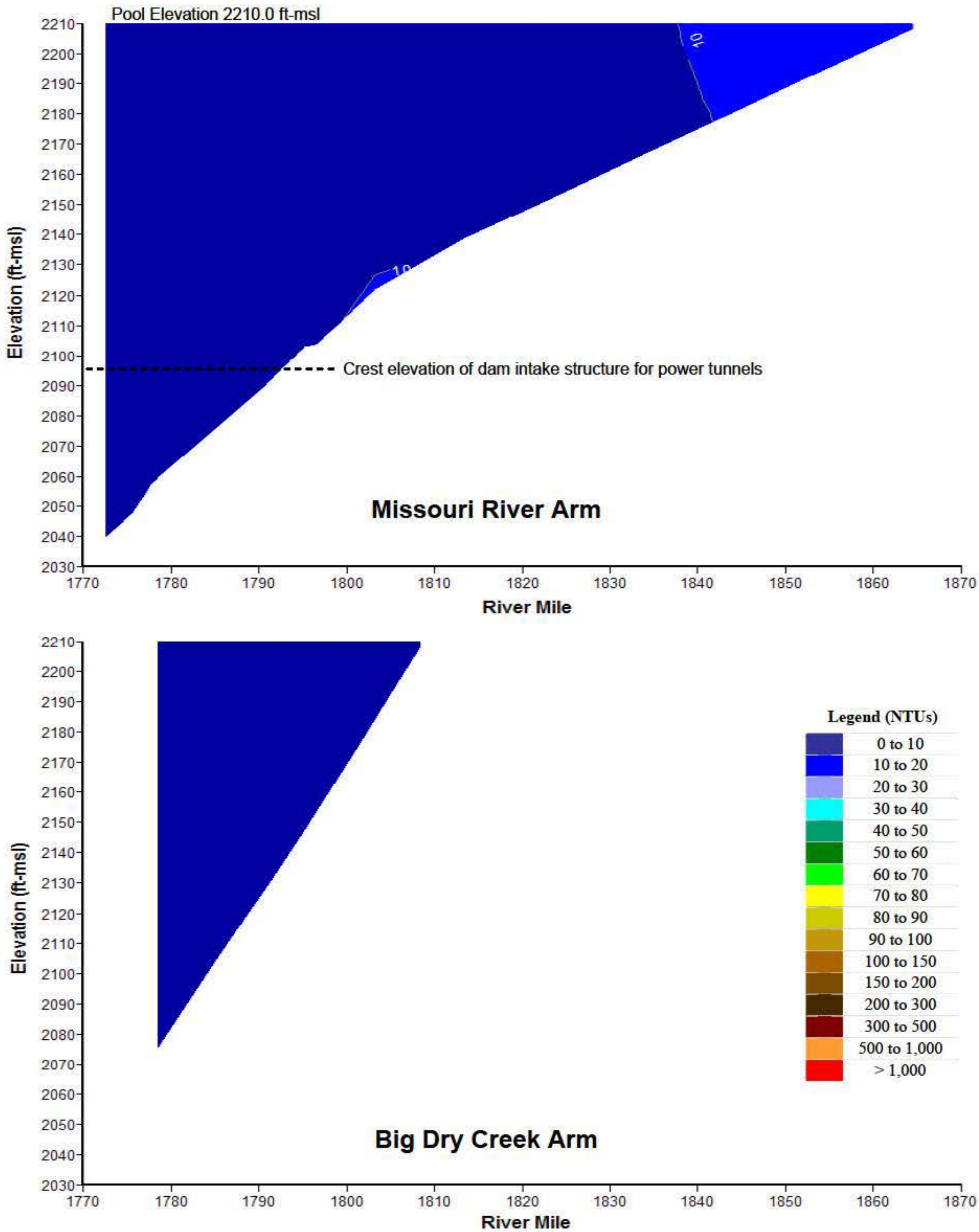


Plate 18. Longitudinal turbidity (NTU) contour plot of Fort Peck Reservoir based on depth-profile turbidity levels monitored at sites FTPLK1772A, FTPLK1805DW, FTPLKBDCA02, and FTPNFMORR1 on August 6, 2008.

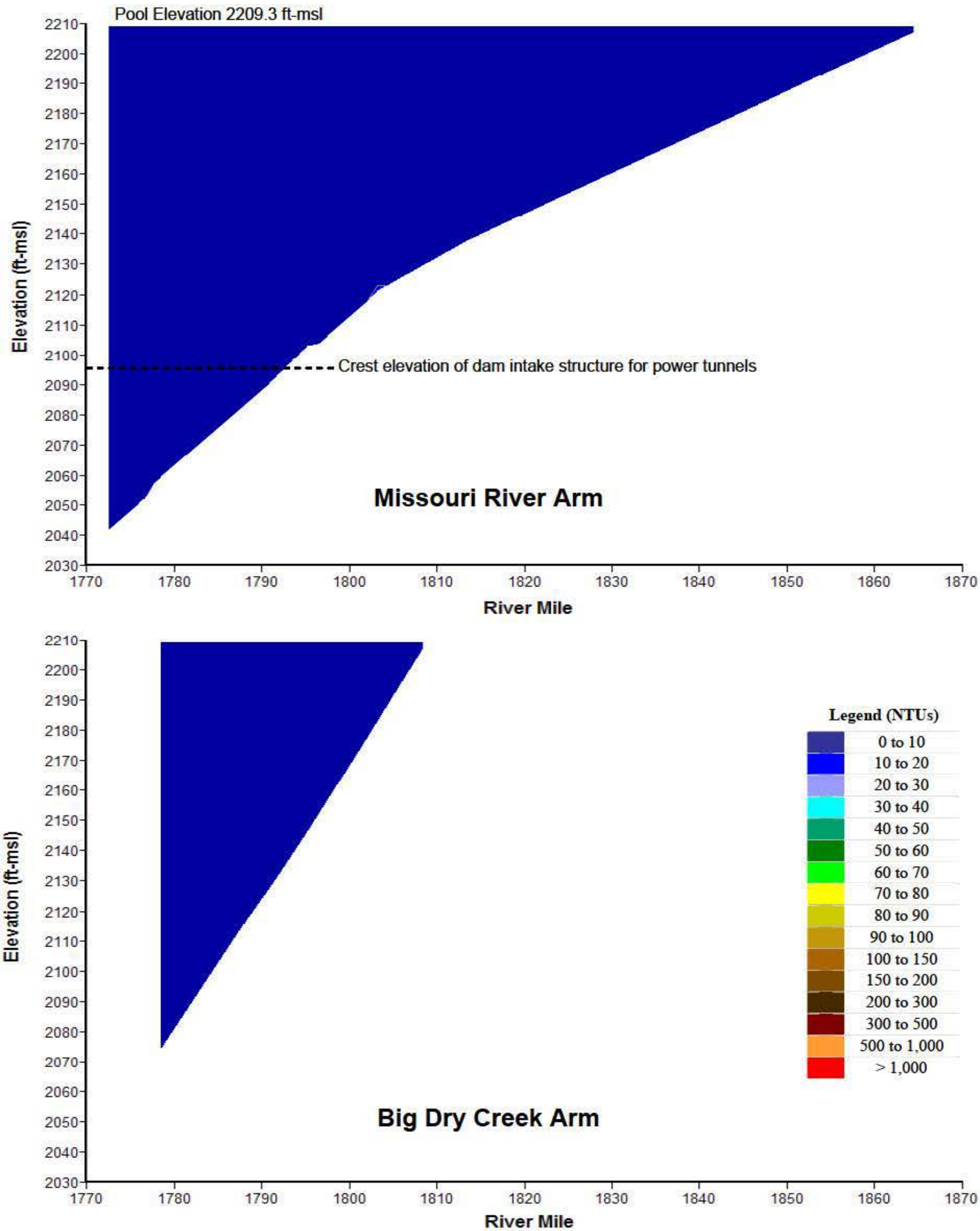


Plate 19. Longitudinal turbidity (NTU) contour plot of Fort Peck Reservoir based on depth-profile turbidity levels monitored at sites FTPLK1772A, FTPLK1805DW, FTPLKBDCA02, and FTPNFMORR1 on September 8, 2008.

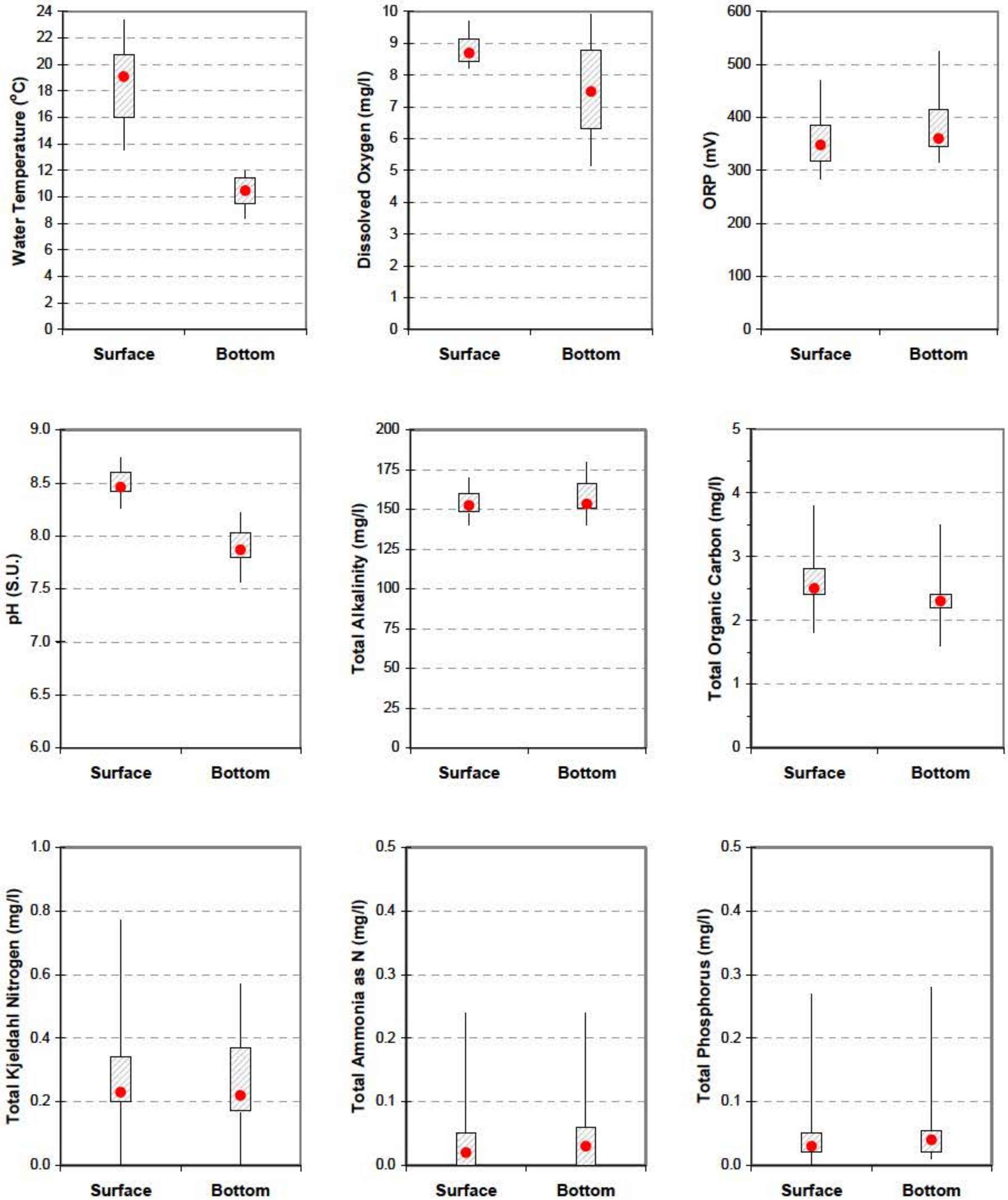


Plate 20. Box plots comparing paired surface and bottom water temperature, dissolved oxygen, oxidation-reduction potential, pH, alkalinity, total organic carbon, total Kjeldahl nitrogen, total ammonia nitrogen, and total phosphorus measurements taken in Fort Peck Reservoir at site FTPLK1772A during the summer months of 2004 through 2008.
(Box plots display minimum, 25th percentile, 75th percentile, and maximum. Median value is indicated by the red dot.)

Plate 21. Total biovolume, number of genera, and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected in Fort Peck Reservoir at site FTPLK1772A during the 5-year period 2004 through 2008.

Date	Total Sample Biovolume (um^3)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta		Shannon-Weaver Genera Diversity
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	
May 2004	785,288	1	0.02	0	-----	0	-----	1	0.57	2	0.41	0	-----	0	-----	0.87
Jun 2004	5,099,022	3	0.21	0	-----	0	-----	1	0.65	3	0.13	0	-----	0	-----	1.15
Jul 2004	106,065,880	3	1.00	0	-----	0	-----	1	<0.01	2	<0.01	0	-----	0	-----	0.96
Aug 2004	47,445,368	4	0.93	1	<0.01	0	-----	1	0.05	3	0.02	0	-----	0	-----	1.59
Sep 2004	47,026,614	6	0.66	7	0.10	0	-----	1	0.09	4	0.09	1	0.05	0	-----	2.11
May 2005	515,757,980	10	0.92	1	<0.01	2	0.07	0	-----	0	-----	0	-----	0	-----	1.28
Jun 2005	46,921,234	5	0.90	1	<0.01	0	-----	0	-----	1	<0.01	1	0.09	0	-----	1.61
Jul 2005	156,655,118	4	0.79	1	<0.01	0	-----	2	0.07	5	0.02	2	0.11	0	-----	1.51
Aug 2005	329,301,346	7	0.46	3	<0.01	1	<0.01	1	0.05	6	0.18	2	0.30	0	-----	2.20
Sep 2005	138,703,297	7	0.38	9	0.08	0	-----	1	<0.01	5	0.05	1	0.47	0	-----	1.62
May 2006	38,868,068	6	0.99	1	0.01	0	-----	0	-----	0	-----	0	-----	1	<0.01	1.17
Jun 2006	106,214,930	4	0.89	2	0.02	1	<0.01	1	<0.01	1	0.08	0	-----	1	<0.01	1.11
Jul 2006	99,703,362	8	0.25	3	0.01	1	0.03	1	0.01	3	0.34	2	0.35	1	0.01	2.12
Aug 2006	146,573,753	6	0.85	3	0.05	0	-----	1	0.03	2	0.07	0	-----	0	-----	1.83
Sep 2006	187,114,896	4	0.95	2	<0.01	0	-----	1	0.04	2	0.01	0	-----	0	-----	1.12
May 2007	1,351,414,254	12	0.99	2	<0.01	1	<0.01	1	<0.01	0	-----	0	-----	0	-----	0.40
Jun 2007	341,943,773	10	0.89	5	<0.01	1	0.05	1	<0.01	2	<0.01	1	<0.01	0	-----	1.49
Jul 2007	164,287,704	7	0.06	3	0.01	1	0.09	1	0.03	3	0.60	2	0.21	0	-----	1.68
Aug 2007	88,444,888	8	0.37	4	0.07	1	0.04	1	0.23	3	0.10	2	0.20	0	-----	2.16
Sep 2007	85,876,002	6	0.69	7	0.06	1	0.02	2	0.07	5	0.12	2	0.04	0	-----	2.28
May 2008	395,506,432	3	1.00	3	<0.01	0	-----	1	<0.01	0	-----	0	-----	0	-----	0.72
Jun 2008	270,305,058	8	0.99	0	-----	2	0.01	0	<0.01	0	-----	0	-----	0	-----	1.09
Jul 2008	777,031	8	0.97	0	-----	1	0.01	1	0.01	2	0.01	2	0.01	0	-----	1.27
Aug 2008	38,049,881	9	0.15	2	0.24	0	-----	1	0.10	2	0.45	2	0.05	0	-----	1.76
Sep 2008	132,911,993	5	0.89	3	0.01	0	-----	1	0.03	4	0.03	2	0.04	0	-----	1.15
Mean*	**193,670,127**	**6.2**	**0.69**	**2.5**	**0.03**	**0.5**	**0.03**	**0.9**	**0.10**	**2.4**	**0.14**	**0.9**	**0.15**	**0.1**	**<0.01**	**1.45**

* Mean percent composition represents the mean when taxa of that division are present.

Plate 22. Total biovolume, number of genera, and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected in Fort Peck Reservoir at site FTPLK1805DW during the 5-year period 2004 through 2008.

Date	Total Sample Biovolume (um^3)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta		Shannon-Weaver Genera Diversity
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	
Jun 2004	40,330,095	7	0.73	0	-----	0	-----	3	0.25	1	0.01	1	0.01	0	-----	1.63
Aug 2004	77,071,993	5	0 53	0	-----	0	-----	2	0.09	6	0.25	1	0.12	0	-----	1.90
Jun 2005	1,065,980,294	6	0.97	3	0.01	2	0.02	1	<0.01	2	<0.01	0	-----	0	-----	1.39
Jul 2005	56,454,155	4	0.62	3	0.01	0	-----	2	0.27	4	0.06	1	0.04	0	-----	1.91
Aug 2005	104,295,158	8	0.36	3	0.14	0	-----	1	0.12	3	0.37	1	<0.01	0	-----	2.21
Sep 2005	224,860,040	4	0.56	4	0.09	2	0.05	2	0.15	3	0.06	2	0.08	0	-----	2.21
Jun 2006	462,062,083	8	0 94	7	0.02	2	0.01	1	0.02	0	-----	0	-----	1	<0.01	1.45
Jul 2006	339,425,190	5	0.19	5	0.10	2	0.03	1	0.22	3	0.43	1	0.03	0	-----	1.95
Oct 2006	342,710,099	9	0.72	12	0.10	1	0.01	1	0.07	3	0.10	1	<0.01	0	-----	2.19
Jun 2007	610,342,167	8	0.67	8	0.05	2	0.13	2	0.07	1	<0.01	1	0.08	0	-----	1.86
Jul 2007	110,206,693	5	0.19	5	0.05	1	<0.01	1	0.22	1	0.08	2	0.46	0	-----	1.64
Aug 2007	301,438,256	9	0.73	10	0.07	1	<0.01	1	0.02	5	0.16	1	0.02	0	-----	1.39
Sep 2007	205,529,265	9	0.34	10	0.19	1	0.01	2	0.10	6	0.01	1	0.35	0	-----	2.01
May 2008	73,487,404	5	0 90	2	0.03	1	0.04	1	0.03	0	-----	0	-----	0	-----	0.76
Jun 2008	1,285,632,120	8	0 96	2	0.02	1	<0.01	1	0.01	0	-----	0	-----	0	-----	1.32
Aug 2008	29,477,027	1	<0.01	4	0.01	1	0.03	1	0.68	6	0.16	1	0.11	0	-----	1.15
Sep 2008	577,974,858	6	0.90	3	0.03	1	<0.01	1	0.06	3	0.01	1	<0.01	0	-----	0.87
Mean*	**347,486,876**	**6.3**	**0.61**	**4.8**	**0.06**	**1.1**	**0.03**	**1.4**	**0.14**	**2.8**	**0.12**	**0.9**	**0.11**	**0.1**	**<0.01**	**1.64**

* Mean percent composition represents the mean when taxa of that division are present.

Plate 23. Total biovolume, number of genera, and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected in Fort Peck Reservoir at site FTPLKBDCA02 during the 5-year period 2004 through 2008.

Date	Total Sample Biovolume (um^3)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta		Shannon-Weaver Genera Diversity
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	
Jun 2004	8,899,939	1	0.67	0	-----	0	-----	2	0.10	4	0.23	0	-----	0	-----	1.14
Jul 2004	50,170,334	5	0.73	0	-----	1	0.02	2	0.15	2	<0.01	2	0.10	0	-----	1.83
Aug 2004	56,170,0417	8	0.77	2	<0.01	0	-----	1	0.08	1	0.14	2	0.01	0	-----	1.68
Sep 2004	259,164,480	4	0.83	4	0.01	1	<0.01	2	0.06	3	0.02	2	0.08	0	-----	1.33
Jun 2005	135,109,593	1	0 31	2	0.02	1	0.64	2	0.01	1	0.02	0	-----	0	-----	0.88
Jul 2005	60,324,919	5	0.47	1	0.03	0	-----	1	0.43	3	0.08	0	-----	0	-----	1.59
Aug 2005	155,331,963	7	0.41	5	0.10	1	0.03	0	-----	5	0.30	1	0.16	0	-----	2.22
Sep 2005	95,486,617	7	0.60	9	0.06	0	-----	2	0.10	5	0.16	1	0.09	0	-----	2.17
Jun 2006	91,137,918	8	0 91	3	0.01	0	-----	1	<0.01	2	0.02	0	-----	2	0.06	0.89
Jul 2006	73,204,385	6	0.11	5	0.07	0	-----	1	0.04	2	0.67	0	-----	2	0.11	1.48
Aug 2006	86,290,748	5	0.60	4	0.05	0	-----	1	0.14	2	0.21	0	-----	0	-----	1.81
Oct 2006	105,358,293	4	0.65	5	0.01	0	-----	1	0.12	2	0.21	1	<0.01	0	-----	1.58
Jun 2007	361,946,003	7	0.72	5	<0.01	1	0.06	1	0.20	1	<0.01	1	0.01	0	----	1.45
Jul 2007	197,258,569	8	0.06	2	0.01	1	0.14	1	0.06	3	0.48	2	0.26	0	-----	1.74
May 2008	54,050,825	8	0.96	1	<0.01	1	0.03	1	0.01	0	-----	0	-----	0	-----	1.43
Jun 2008	359,698,227	8	1.00	2	<0.01	1	<0.01	1	<0.01	0	-----	0	-----	0	-----	0.65
Jul 2008	317,482	2	0 91	3	0.01	1	<0.01	1	0.01	2	0.07	1	0.01	0	-----	1.12
Aug 2008	22,438,138	2	0.02	2	0.05	0	-----	1	0.51	3	0.41	1	0.01	0	-----	1.16
Sep 2008	122,457,717	4	0.82	1	<0.01	0	-----	1	0.11	0	-----	1	0.07	0	-----	0.97
Mean*	**147,386,661**	**5.3**	**0.61**	**2 9**	**0.03**	**0.5**	**0.10**	**1.2**	**0.12**	**2.2**	**0.19**	**0 8**	**0.07**	**0.2**	**0.09**	**1.43**

* Mean percent composition represents the mean when taxa of that division are present.

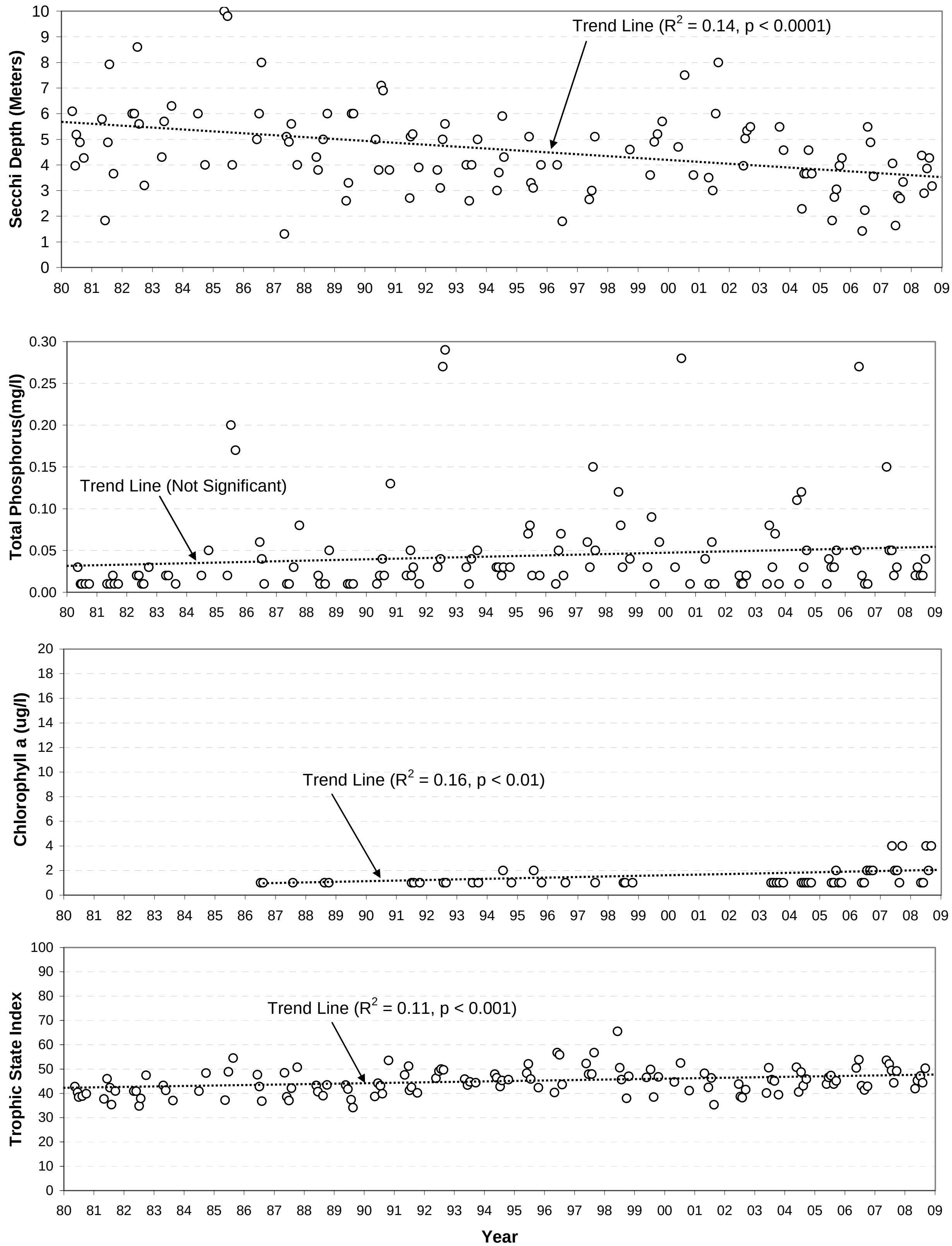


Plate 24. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and Trophic State Index (TSI) monitored in Fort Peck Reservoir at site FTPLK1772A over the 29-year period of 1980 through 2008.

Plate 25. Summary of monthly (April through September) water quality conditions monitored in the Missouri River near Landusky, Montana at monitoring site FTPNFMORR1 during the 5-year period 2004 through 2008.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit[A]	No. of Obs.	Mean[B]	Median	Min.	Max.	State WQS Criteria[C]	No. of WQS Exceedences	Percent WQS Exceedence
Stream Flow (cfs)	1	23	7,586	7,210	3,978	17,500	-----	-----	-----
Water Temperature (C)	0.1	23	17.8	16.4	10.7	26.4	26.7[1,2]	0	0%
Dissolved Oxygen (mg/l)	0.1	23	8.6	8.6	7.0	10.5	5.0[1,3]	0	0%
Dissolved Oxygen (% Sat.)	0.1	23	93.0	92.0	81.2	102.0	-----	-----	-----
pH (S.U.)	0.1	23	8.5	8.5	8.0	8.9	6.5[1,3], 9.0[1,2]	0	0%
Specific Conductance (umho/cm)	1	23	463	444	342	696	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	23	340	327	266	436	-----	-----	-----
Turbidity (NTU)	1	23	394	60	1	3,000	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	12	19	7	n.d.	105	-----	-----	-----
Alkalinity, Total (mg/l)	7	23	147	144	120	175	-----	-----	-----
Ammonia, Total (mg/l)	0.02	23	-----	0.06	n.d.	0.46	3.2 [1,2,4], 1.5[1,4,5]	0	0%
Carbon, Total Organic (mg/l)	0.05	22	2.8	2.7	1.2	4.2	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	16	23	12	4	171	-----	-----	-----
Chloride, Dissolved (mg/l)	1	15	8	8	6	11	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	22	321	294	250	509	-----	-----	-----
Hardness, Total (mg/l)	0.4	2	187	187	179	194	-----	-----	-----
Iron, Dissolved (ug/l)	40	15	-----	n.d.	n.d.	230	-----	-----	-----
Iron, Total (ug/l)	40	15	16,542	3,047	684	145,000	1,000[7], 300[9]	13, 15	87%, 100%
Kjeldahl N, Total (mg/l)	0.1	23	1.0	0.6	0.2	5.9	-----	-----	-----
Manganese, Dissolved (ug/l)	2	14	5	4	n.d	20	-----	-----	-----
Manganese, Total (ug/l)	2	15	194	62	21	1,460	50[9]	8	53%
Nitrate-Nitrite N, Total (mg/l)	0.02	23	-----	0.03	n.d.	0.20	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	22	-----	0.02	n.d.	0.07	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	23	0.44	0.12	0.03	4.70	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	23	-----	n.d.	n.d.	0.03	-----	-----	-----
Sulfate (mg/l)	1	23	95	83	51	229	-----	-----	-----
Suspended Solids, Total (mg/l)	4	23	603	108	19	7,437	-----	-----	-----
Aluminum, Dissolved (ug/l)	25	2	-----	n.d.	n.d.	n.d.	750[6], 87[7]	0	0%
Antimony, Total (ug/l)	0.5	2	-----	2.5	n.d.	5.0	5.6[6]	0	0%
Arsenic, Total (ug/l)	1	2	14	14	14	14	340[6], 150[7], 10[8]	0, 0, 2	0%, 0%, 100%
Barium, Total (ug/l)	5	2	69	69	69	70	2,000[8]	0	0%
Beryllium, Total (ug/l)	2	2	-----	n.d.	n.d.	n.d.	4[8]	0	0%
Cadmium, Total (ug/l)	0.2	2	-----	n.d.	n.d.	n.d.	4.0[6], 0.43[7], 5[8]	0	0%
Chromium, Total (ug/l)	10	2	-----	n.d.	n.d.	n.d.	3,010[6], 144[7], 100[8]	0	0%
Copper, Total (ug/l)	2	2	-----	n.d.	n.d.	n.d.	25.2[6], 15.9[7], 1,300[8]	0	0%
Lead, Total (ug/l)	0.5	2	0.8	0.8	0.6	1.0	181[6], 7.1[7], 15[8]	0	0%
Mercury, Total (ug/l)	0.02	2	-----	n.d.	n.d.	n.d.	1.7[6], 0.91[7], 0.05[8]	0	0%
Nickel, Total (ug/l)	10	2	-----	n.d.	n.d.	n.d.	797[6], 89[7], 100[8]	0	0%
Selenium, Total (ug/l)	1	3	-----	n.d.	n.d.	1	20[6], 5[7], 50[8]	0	0%
Silver, Total (ug/l)	1	2	-----	n.d.	n.d.	n.d.	11 9[6], 100[8]	0	0%
Thallium, Total (ug/l)	0.5	2	-----	n.d.	n.d.	n.d.	0.24[8]	b.d.	b.d.
Zinc, Total (ug/l)	10	2	-----	n.d.	n.d.	70	204[6,7], 2,000[8]	0	0%
Pesticide Scan (ug/l)[D]	0.05	2	-----	-----	-----	-----	-----	-----	-----

n.d. = Not detected. b.d. = Criterion below detection limit.

(A) Detection limits given for the parameters Stream Flow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d , mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for B-3 classified waters.
- (2) Daily maximum criterion (monitoring results directly comparable to criterion).
- (3) Daily minimum criterion (monitoring results directly comparable to criterion).
- (4) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (5) 30-day average criterion (monitoring results not directly comparable to criterion).
- (6) Acute criterion for aquatic life.
- (7) Chronic criterion for aquatic life.
- (8) Human health criterion for surface waters.
- (9) Secondary Maximum Contaminant Level based on aesthetic properties.

Note: Some of Montana's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

(D) The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, cycloate, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, isopropalin, metolachlor, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, phorate, profluralin, prometon, propachlor, propazine, simazine, terbufos, triallate, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

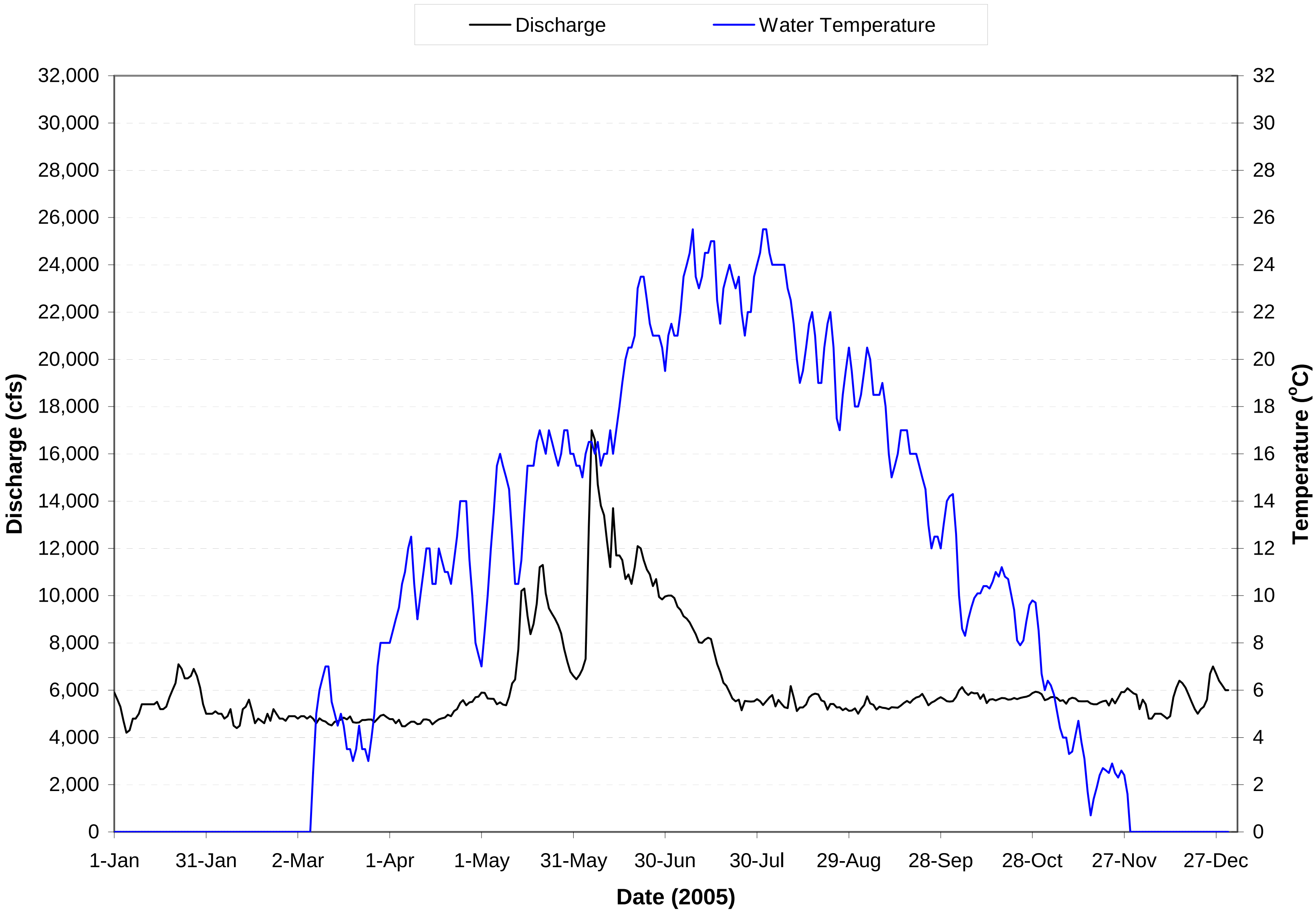


Plate 26. Mean daily discharge and water temperature of the Missouri River near Landusky, Montana (i.e., site FTPNFMORR1) for 2005. Means based on measurements recorded at USGS gaging station 06115200.

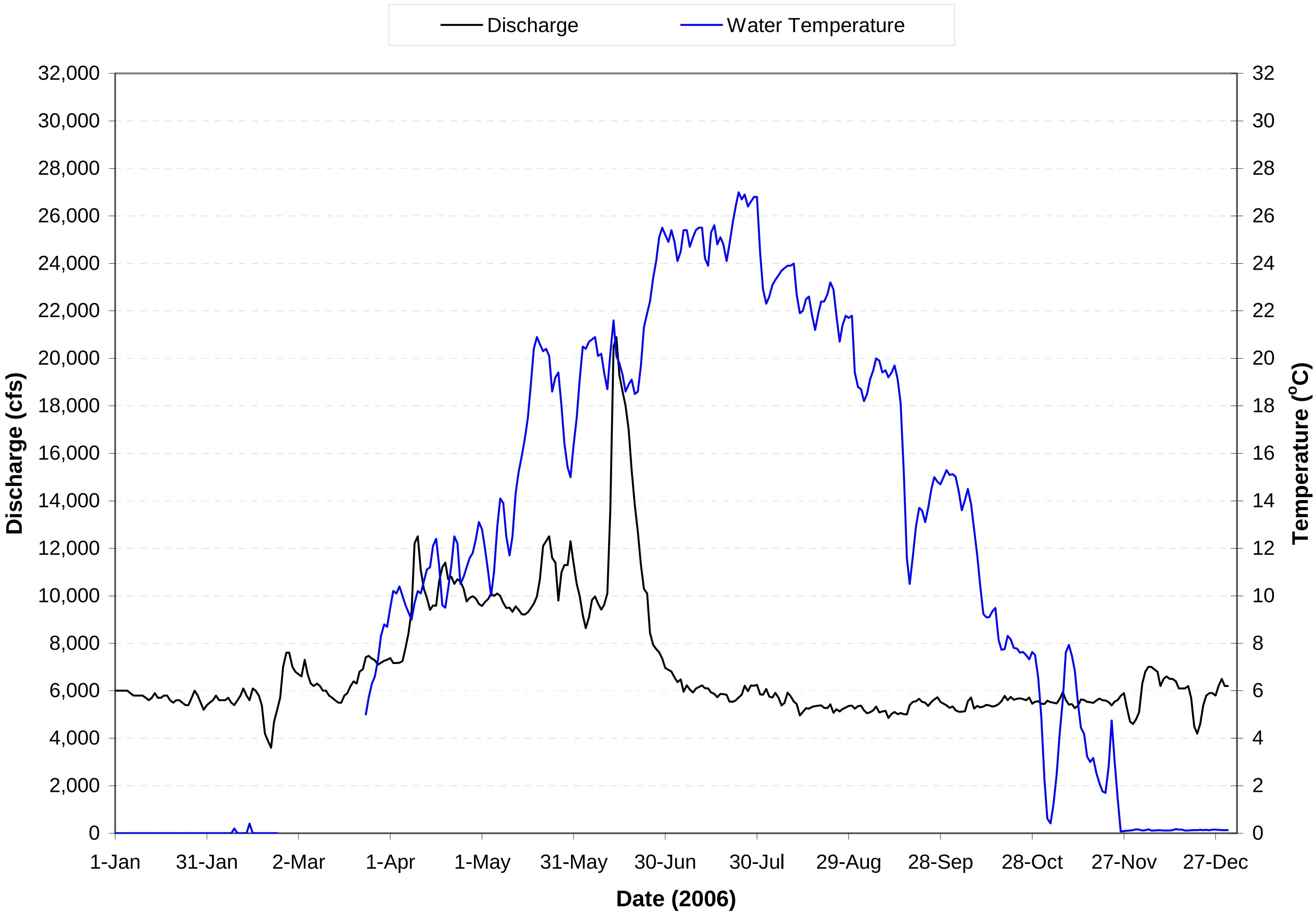


Plate 27. Mean daily discharge and water temperature of the Missouri River near Landusky, Montana (i.e., site FTPNFMORR1) for 2006. Means based on measurements recorded at USGS gaging station 06115200.

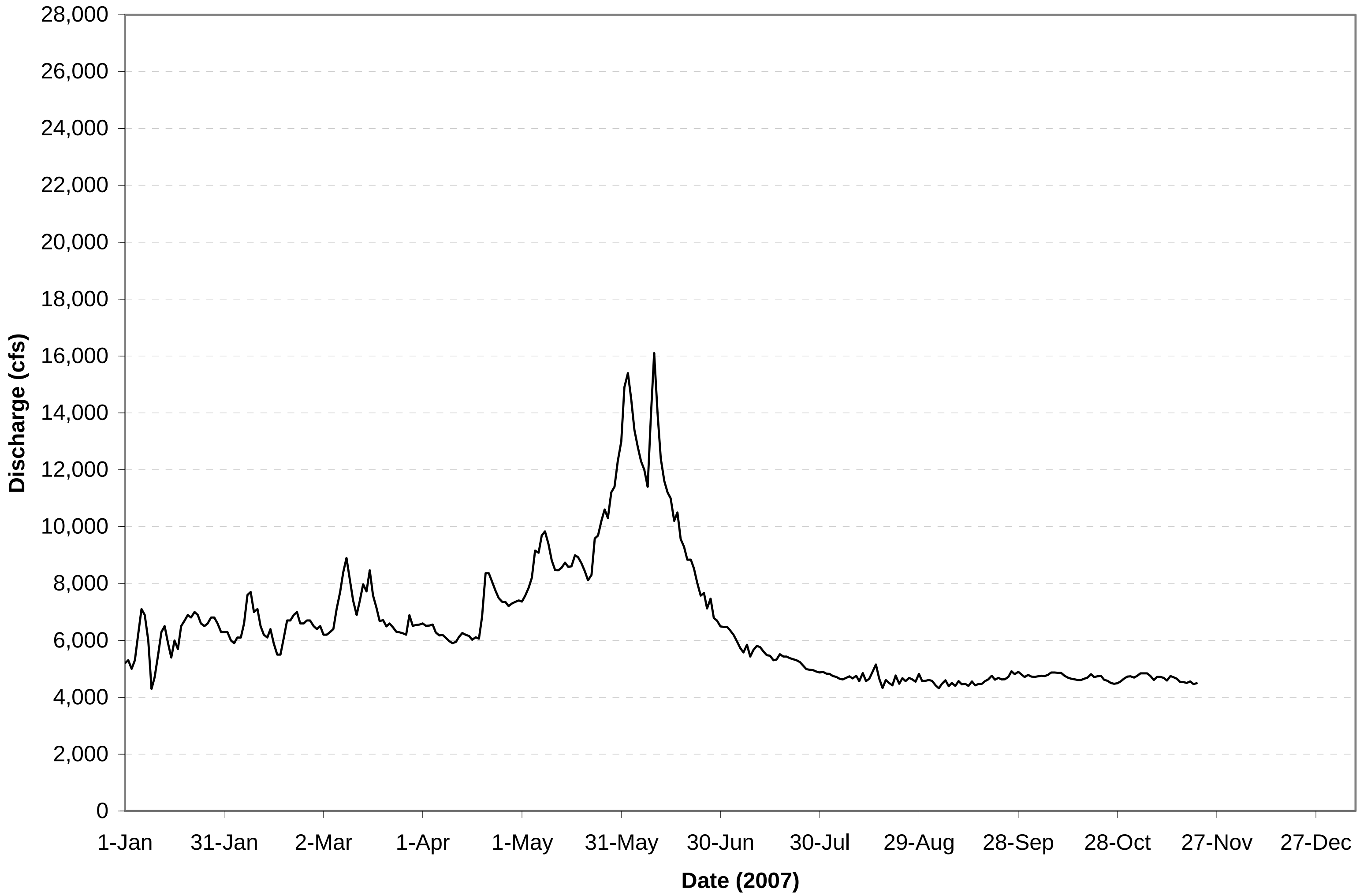


Plate 28. Mean daily discharge of the Missouri River near Landusky, Montana (i.e., site FTPNFMORR1) for 2007. Means based on measurements recorded at USGS gaging station 06115200.

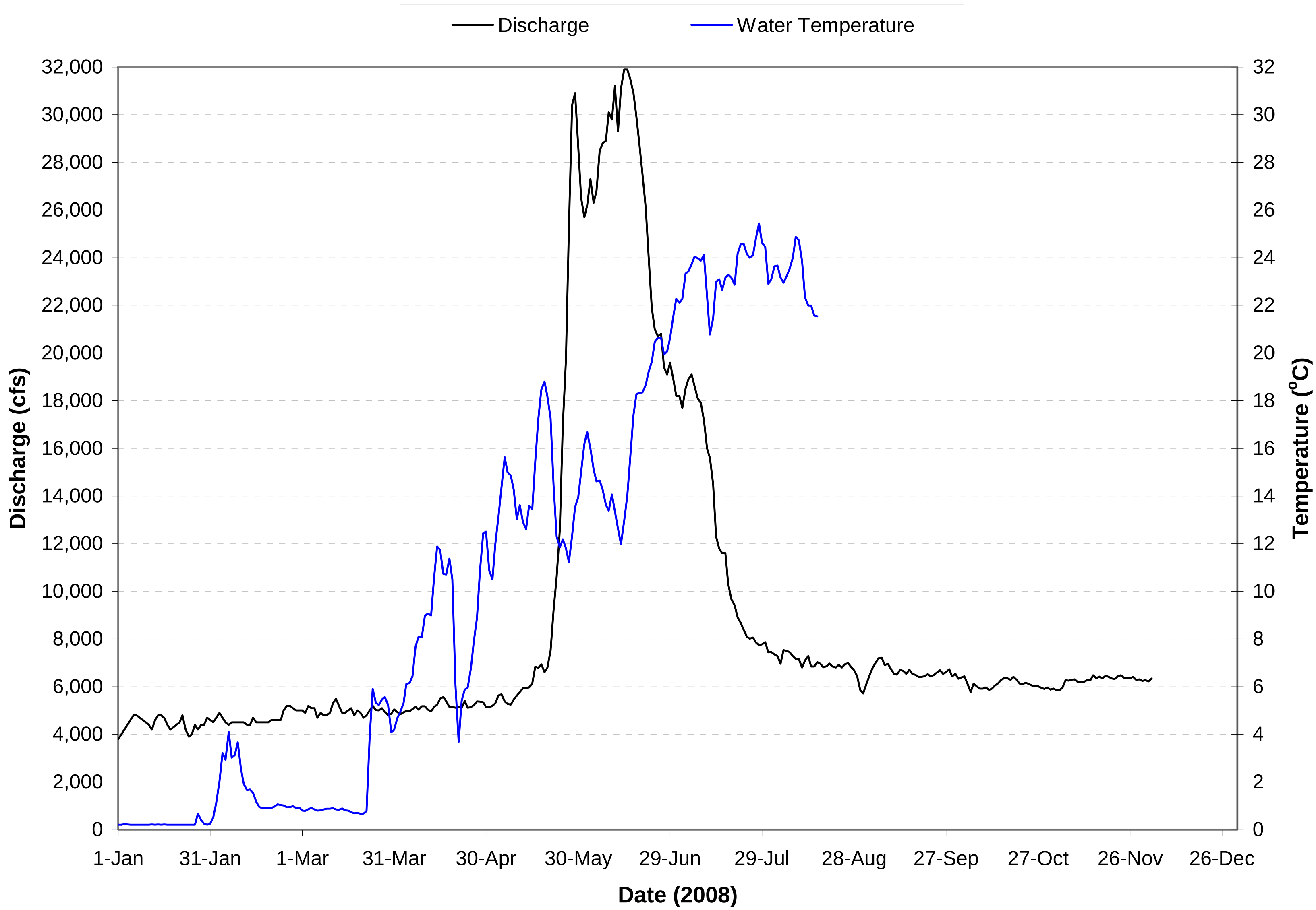


Plate 29. Mean daily discharge and water temperature of the Missouri River near Landusky, Montana (i.e., site FTPNFMORR1) for 2008. Means based on measurements recorded at USGS gaging station 06115200.

Plate 30. Summary of water quality conditions monitored on water discharged through Fort Peck Dam (i.e., site FTPPP1) during the 5-year period of January 2004 through December 2008.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit[A]	No. of Obs.	Mean[B]	Median	Min.	Max.	State WQS Criteria[C]	No. of WQS Exceedences	Percent WQS Exceedence
Dam Discharge (cfs)	1	48	6,645	6,092	3,00	12,513	-----	-----	-----
Water Temperature (C)	0.1	46	9.5	9.9	1.4	17.3	19.4[1,4]	0	0%
Dissolved Oxygen (mg/l)	0.1	46	10.0	9.8	6.0	13.8	8.0[1,2,4], 4.0[1,3,4]	8, 0	17%, 0%
Dissolved Oxygen (% Sat.)	0.1	46	90.8	92.7	62.7	103.6	-----	-----	-----
pH (S.U.)	0.1	42	8.3	8.3	7.8	8.7	6.5[1,5], 9.0[1,4]	0	0%
Specific Conductance (umho/cm)	1	46	522	536	405	704	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	28	386	365	300	575	-----	-----	-----
Turbidity (NTU)	0.1	25	2	2	n.d.	6	-----	-----	-----
Alkalinity, Total (mg/l)	7	48	160	160	140	180	-----	-----	-----
Ammonia, Total (mg/l)	0.02	48	-----	0.02	n.d.	0.51	3.1 [1,4,6], 1.4 [1,4,7]	0	0%
Carbon, Total Organic (mg/l)	0.05	47	2.7	2.5	1.0	5.3	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	31	8	8	n.d.	41	-----	-----	-----
Chloride, Dissolved (mg/l)	1	29	9	9	7	17	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	48	364	350	306	496	-----	-----	-----
Hardness, Total (mg/l)	0.4	7	204	208	174	217	-----	-----	-----
Iron, Dissolved (ug/l)	40	30	-----	n.d.	n.d.	40	-----	-----	-----
Iron, Total (ug/l)	40	31	200	115	n.d.	2,015	1,000[9], 300[11]	1, 3	3%, 10%
Kjeldahl N, Total (mg/l)	0.1	48	0.4	0.3	n.d.	2.2	-----	-----	-----
Manganese, Dissolved (ug/l)	2	30	-----	1	n.d.	10	-----	-----	-----
Manganese, Total (ug/l)	2	30	8	6	n.d.	38	50[11]	0	0%
Nitrate-Nitrite N, Total (mg/l)	0.02	48	-----	n.d.	n.d.	0.11	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.02	39	-----	n.d.	n.d.	0.08	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	48	----	0.03	n.d.	0.14	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	48	-----	n.d.	n.d.	0.03	-----	-----	-----
Sulfate (mg/l)	1	48	130	123	57	209	-----	-----	-----
Suspended Solids, Total (mg/l)	4	48	-----	n.d.	n.d.	80	-----	-----	-----
Aluminum, Dissolved (ug/l)	25	2	-----	n.d.	n.d.	n.d.	750[8], 87[9]	0	0%
Antimony, Total (ug/l)	0.5	2	-----	n.d.	n.d.	0.5	5.6[11]	0	0%
Arsenic, Total (ug/l)	1	2	4	4	4	4	340[8], 150[9], 10[10]	0	0%
Barium, Total (ug/l)	5	2	45	45	39	50	2,000[10]	0	0%
Beryllium, Total (ug/l)	2	2	-----	n.d.	n.d.	n.d.	4[10]	0	0%
Cadmium, Total (ug/l)	0.2	2	-----	n.d.	n.d.	n.d.	4.5[8], 0.47[9], 5[10]	0	0%
Chromium, Total (ug/l)	10	2	-----	n.d.	n.d.	n.d.	3,285[8], 157[9], 100[10]	0	0%
Copper, Total (ug/l)	2	2	-----	n.d.	n.d.	n.d.	28[8], 17[9], 1,300[10]	0	0%
Lead, Total (ug/l)	0.5	2	-----	1.0	n.d.	2.0	207[8], 8 1[9], 15[10]	0	0%
Mercury, Total (ug/l)	0.02	7	-----	n.d.	n.d.	n.d.	1.7[8], 0.91[9], 0.05[10]	0	0%
Nickel, Total (ug/l)	10	2	-----	n.d.	n.d.	n.d.	872[8], 97[9], 100[10]	0	0%
Selenium, Total (ug/l)	1	6	-----	n.d.	n.d.	n.d.	20[8], 5[9], 50[10]	0	0%
Silver, Total (ug/l)	1	2	-----	n.d.	n.d.	n.d.	14[8], 100[10]	0	0%
Thallium, Total (ug/l)	0.5	2	-----	n.d.	n.d.	n.d.	0.24[10]	b.d.	b.d.
Zinc, Total (ug/l)	10	2	-----	20	n.d.	40	223[8,9], 2,000[10]	0	0%
Pesticide Scan (ug/l)[D]	0.05	2	-----	n.d.	n.d.	n.d.	-----	-----	-----

n.d. = Not detected. b.d. = Criterion below detection limit.

[A] Detection limits given for the parameters Stream Flow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

[B] Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

[C] Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- [1] Criteria for B-3 classified waters.
- [2] Early life stages.
- [3] Non-early life stages.
- [4] Daily maximum criterion (monitoring results directly comparable to criterion).
- [5] Daily minimum criterion (monitoring results directly comparable to criterion).
- [6] Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- [7] 30-day average criterion (monitoring results not directly comparable to criterion).
- [8] Acute criterion for aquatic life.
- [9] Chronic criterion for aquatic life.
- [10] Human health criterion for surface waters.
- [11] Secondary Maximum Contaminant Level based on aesthetic properties.

Note: Some of Montana's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

[D] The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, cycloate, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, isopropalin, metolachlor, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, phorate, profluralin, prometon, propachlor, propazine, simazine, terbufos, triallate, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

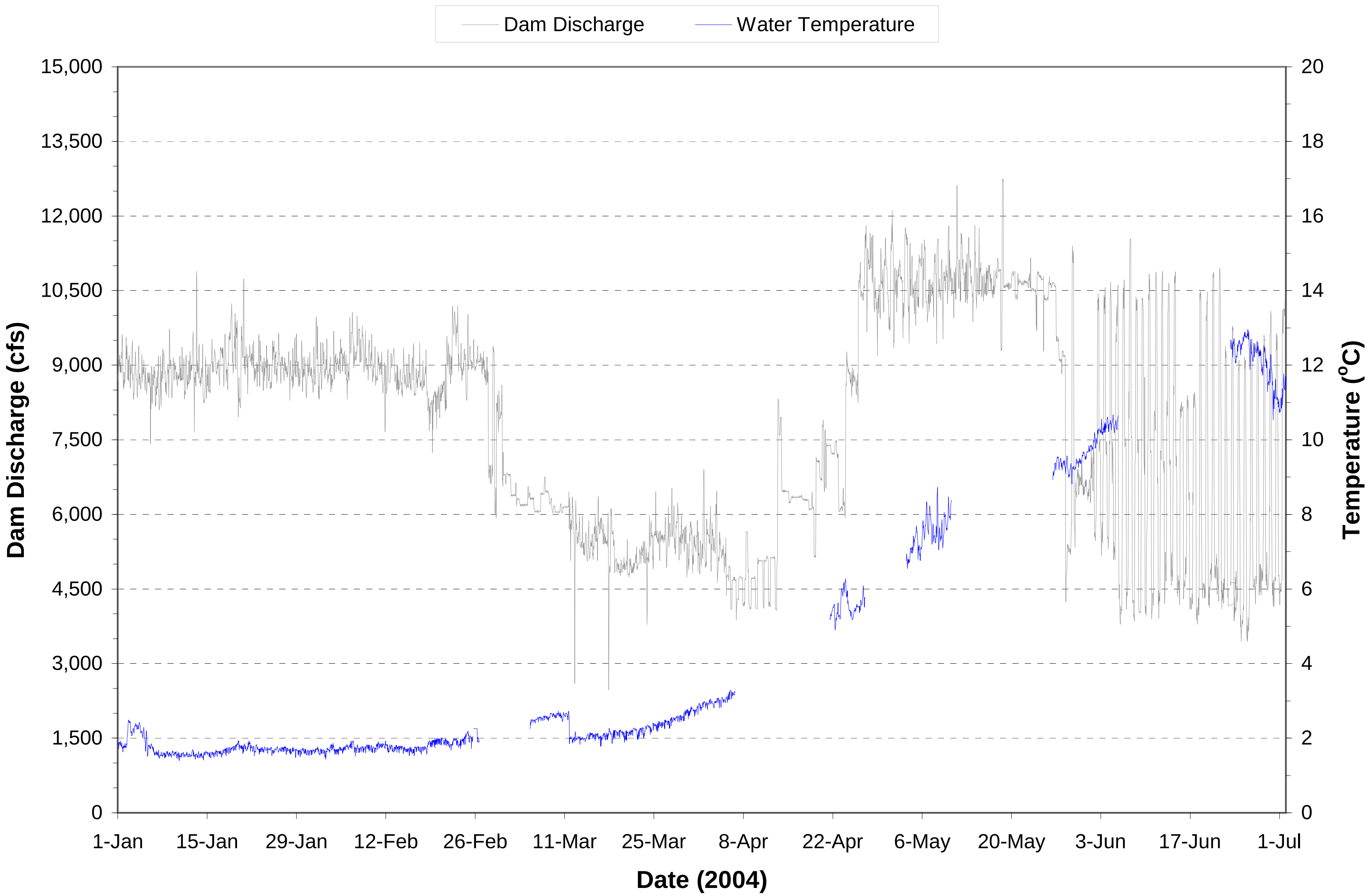


Plate 31. Hourly discharge and water temperature monitored at the Fort Peck powerplant on water discharged through the dam during the period January through June 2004.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

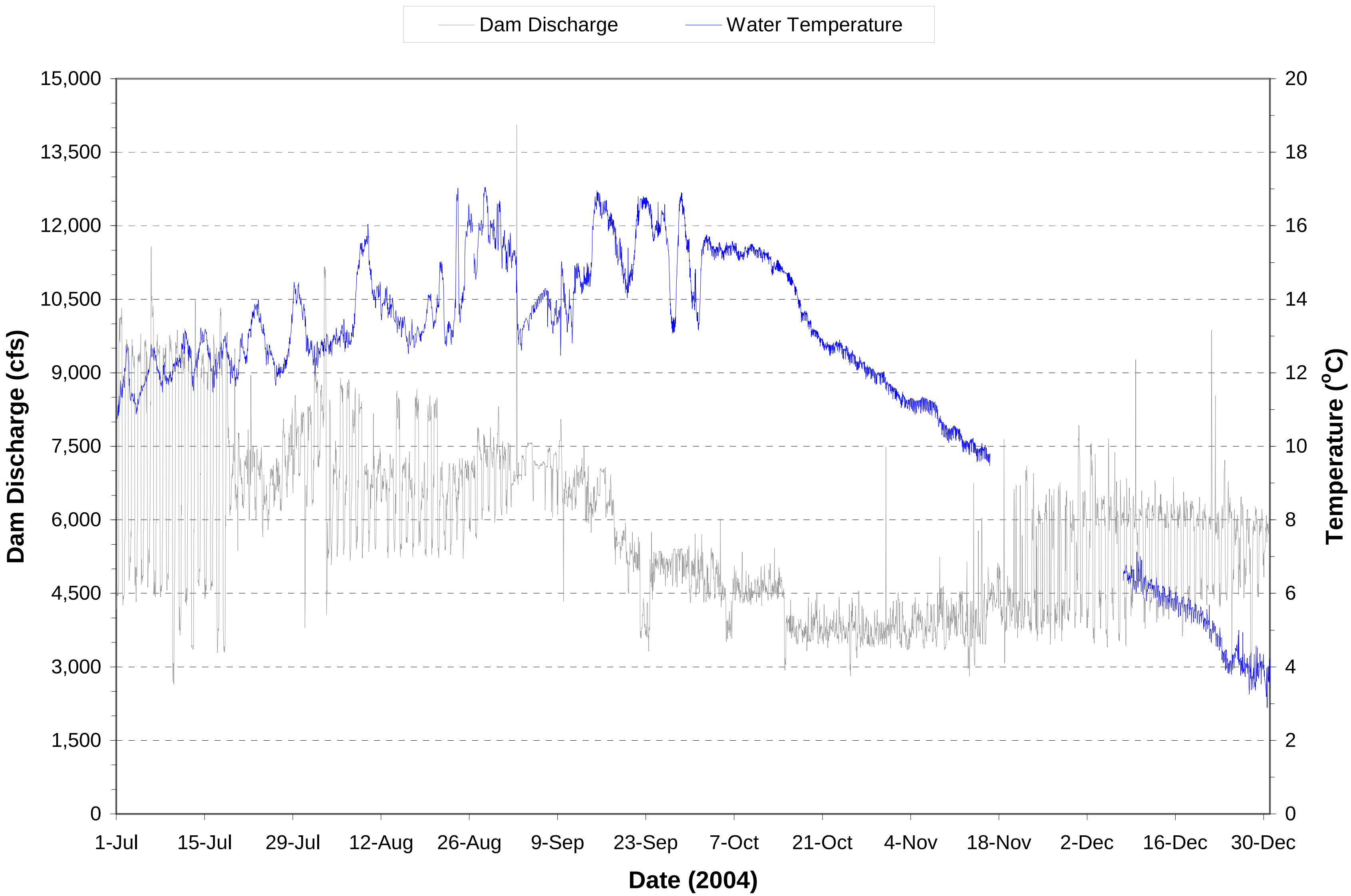


Plate 32. Hourly discharge and water temperature monitored at the Fort Peck powerplant on water discharged through the dam during the period July through December 2004.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

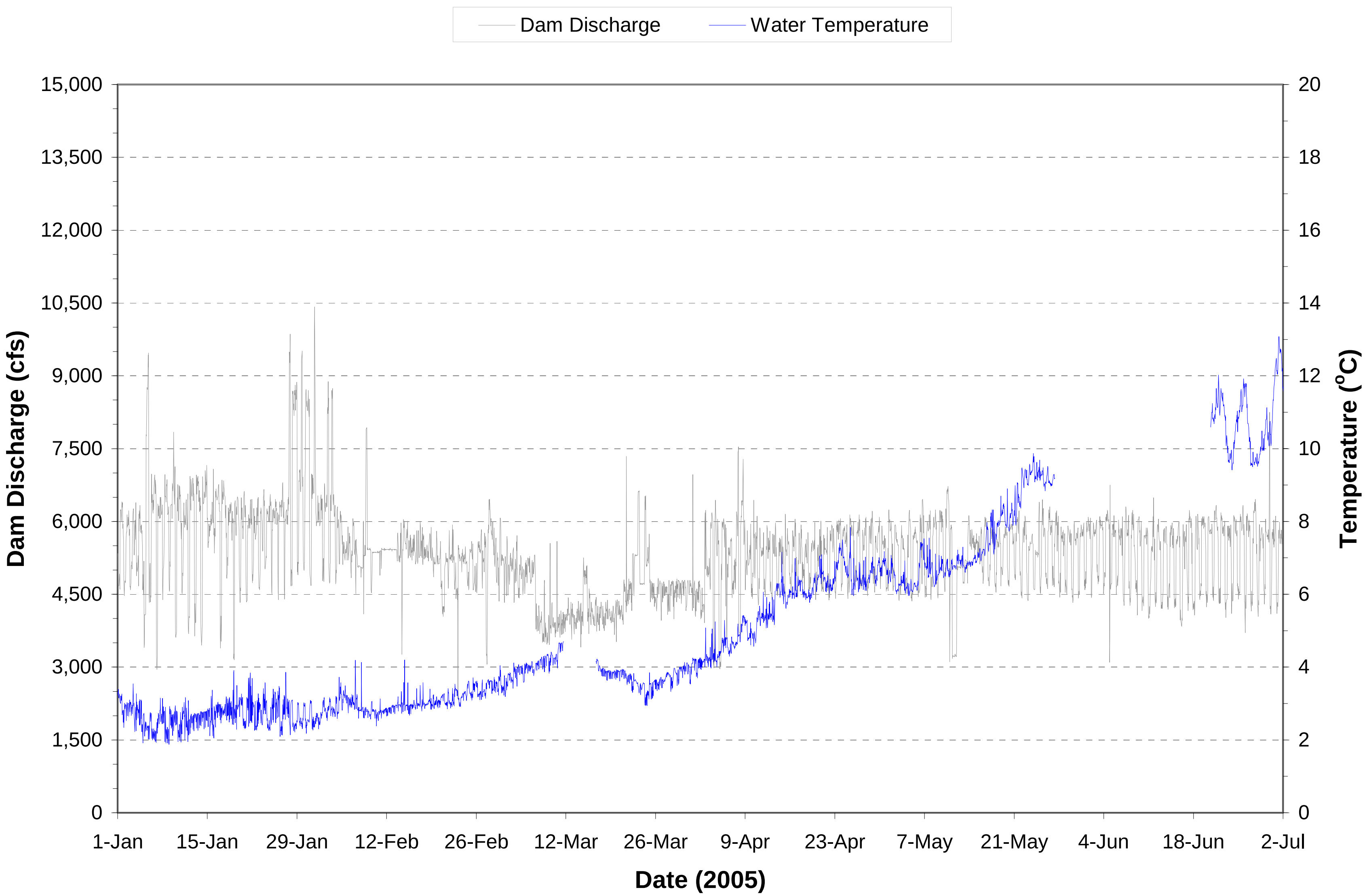


Plate 33. Hourly discharge and water temperature monitored at the Fort Peck powerplant on water discharged through the dam during the period January through June 2005.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

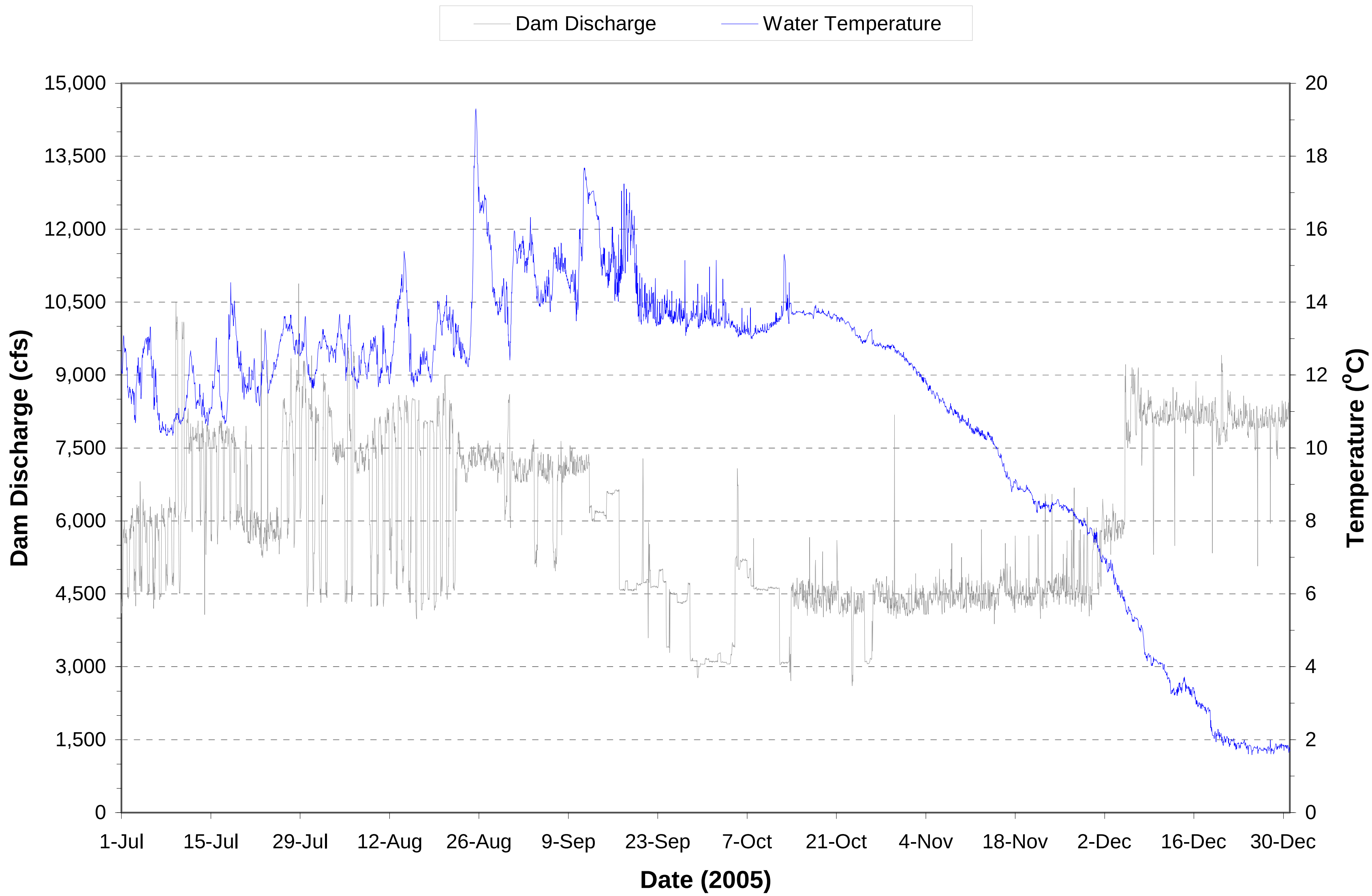


Plate 34. Hourly discharge and water temperature monitored at the Fort Peck powerplant on water discharged through the dam during the period July through December 2005.

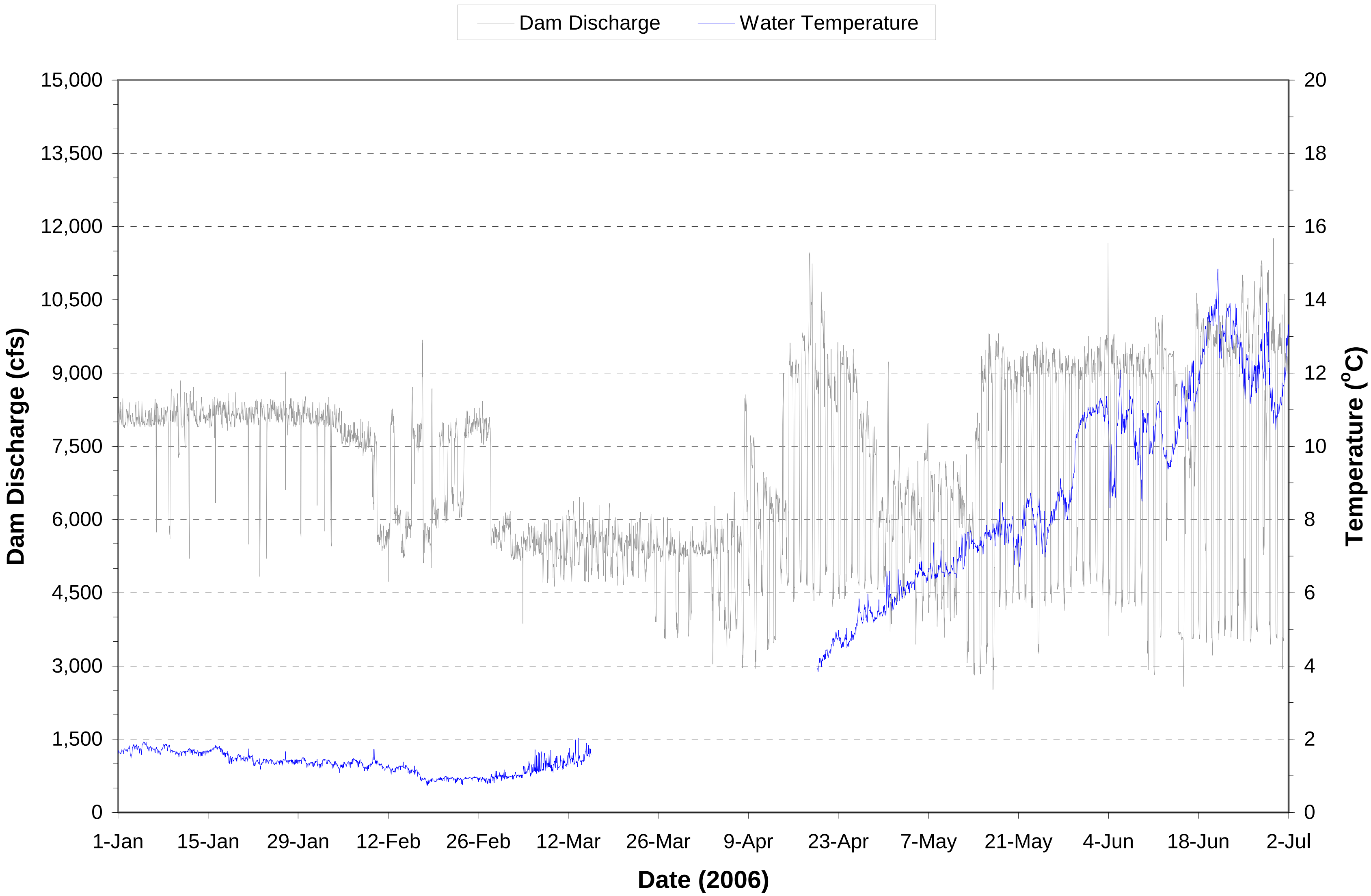


Plate 35. Hourly discharge and water temperature monitored at the Fort Peck powerplant on water discharged through the dam during the period January through June 2006.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

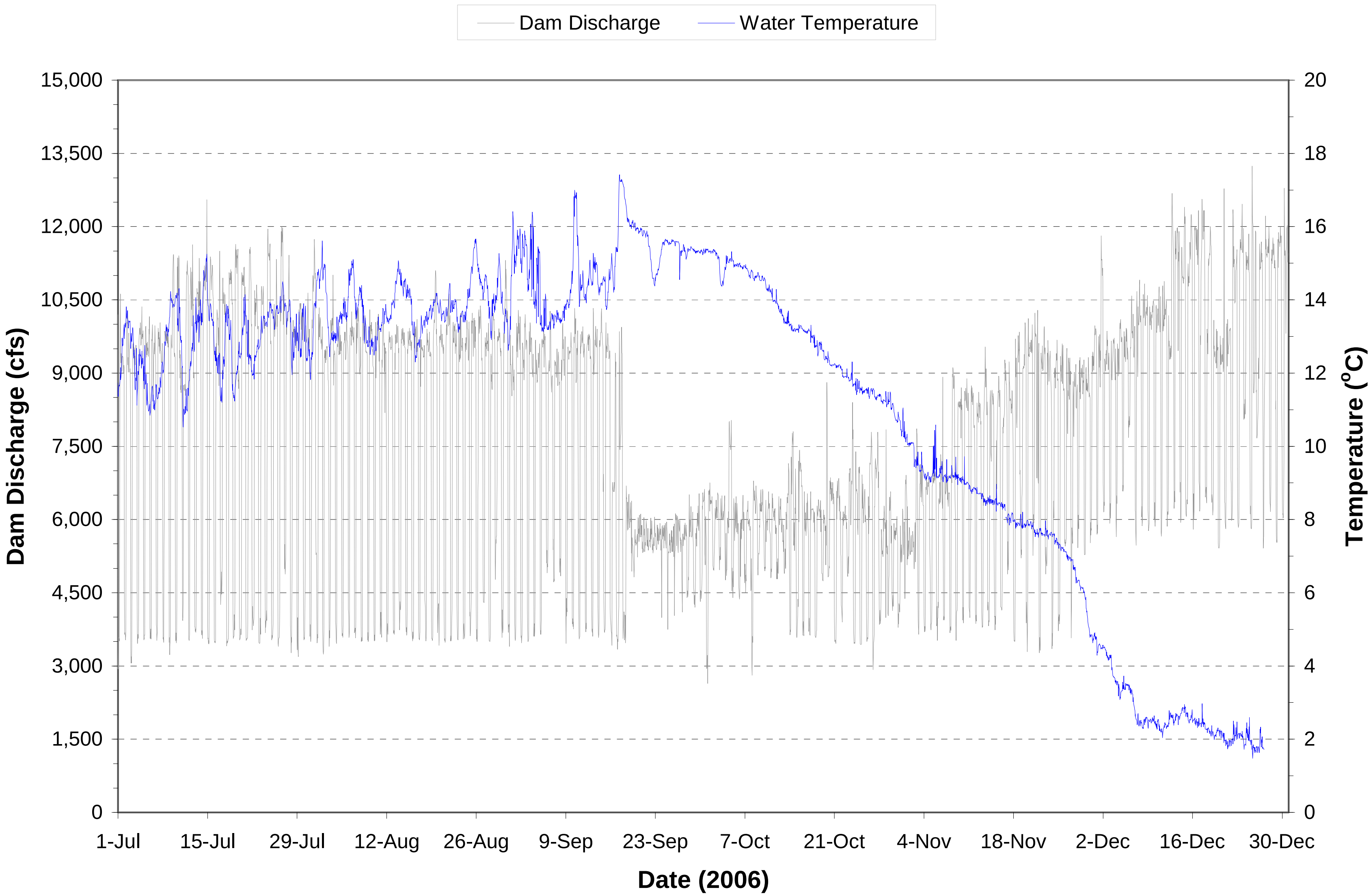


Plate 36. Hourly discharge and water temperature monitored at the Fort Peck powerplant on water discharged through the dam during the period July through December 2006.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

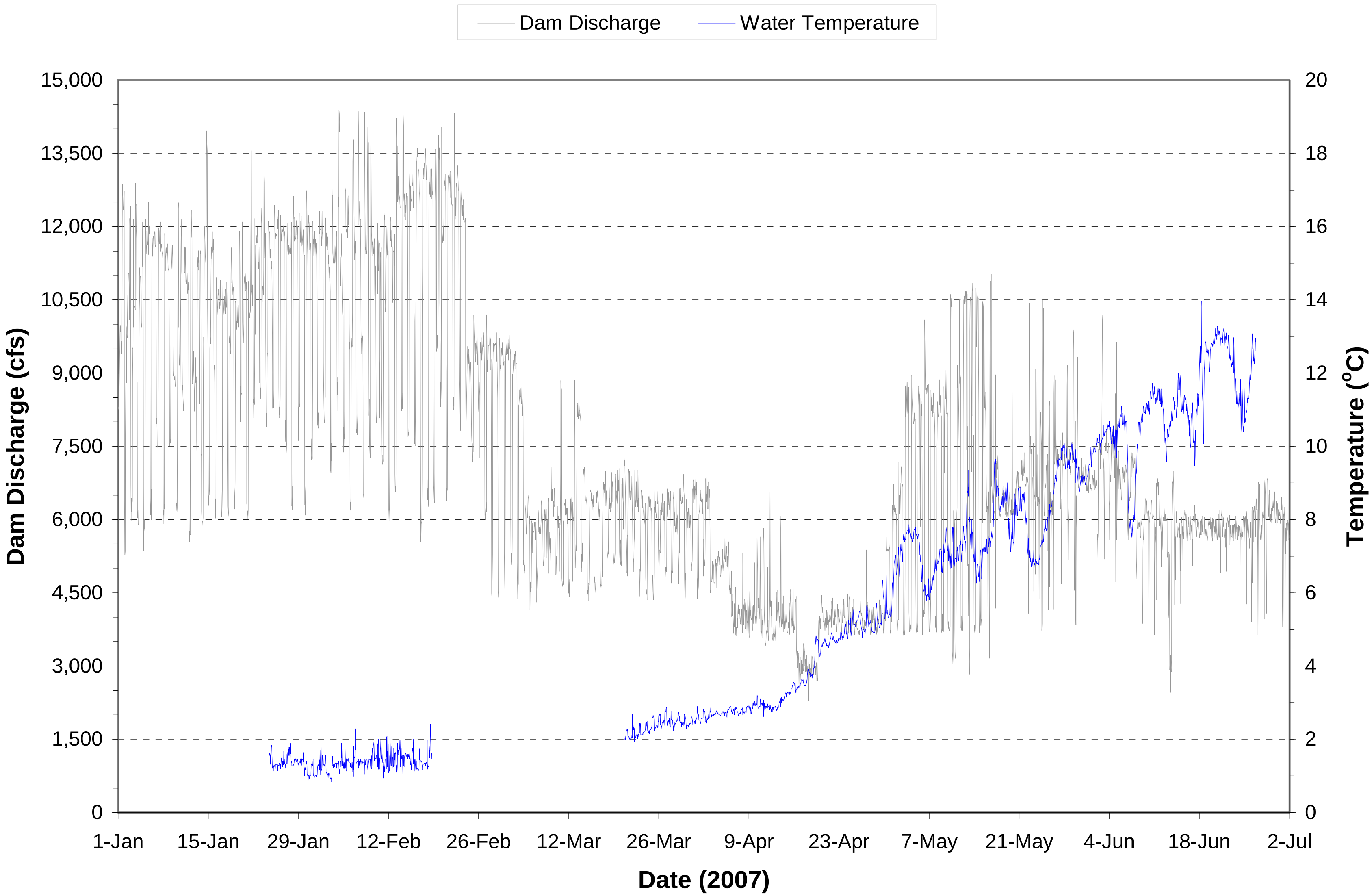


Plate 37. Hourly discharge and water temperature monitored at the Fort Peck powerplant on water discharged through the dam during the period January through June 2007.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

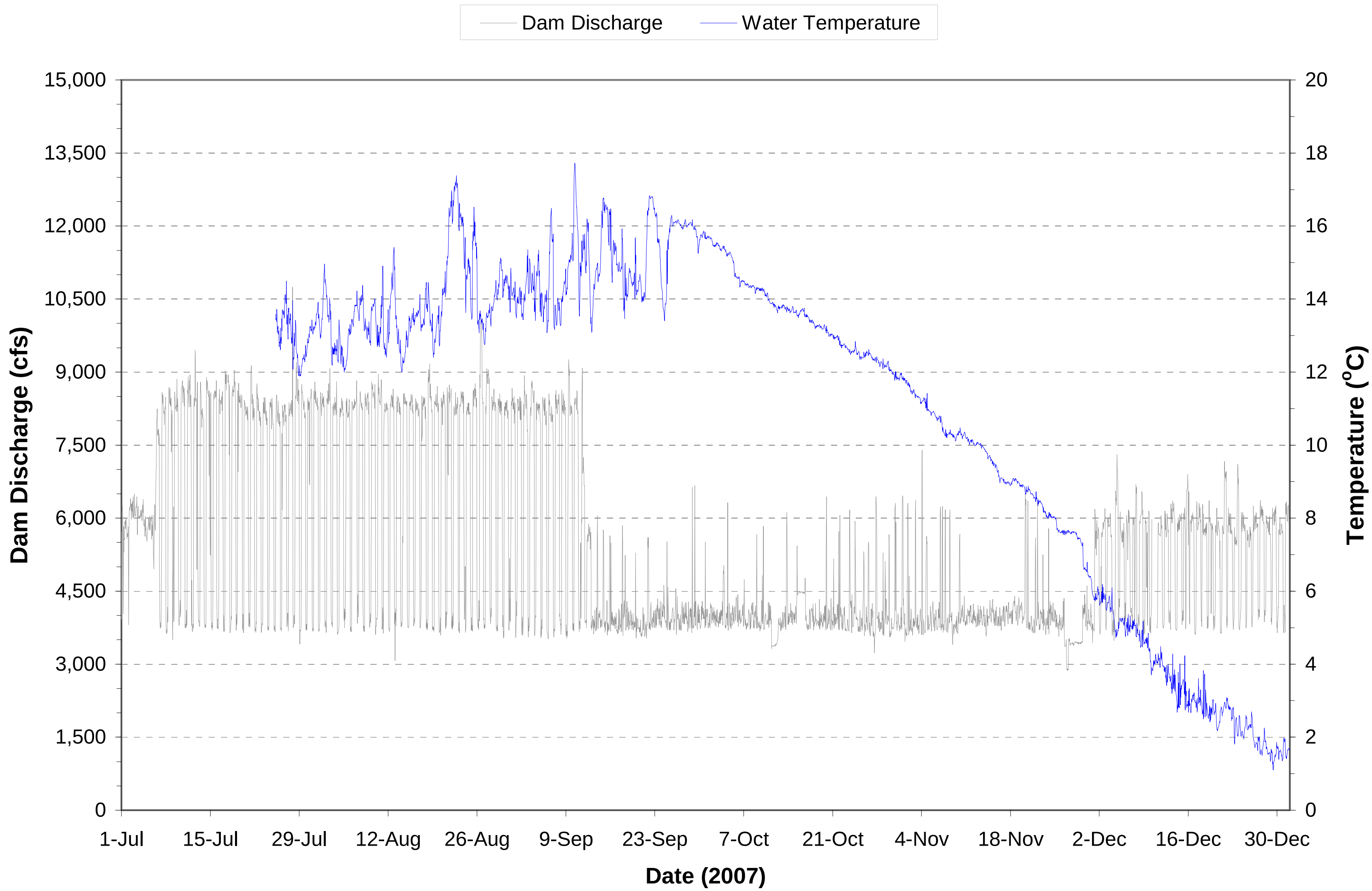


Plate 38. Hourly discharge and water temperature monitored at the Fort Peck powerplant on water discharged through the dam during the period July through December 2007.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

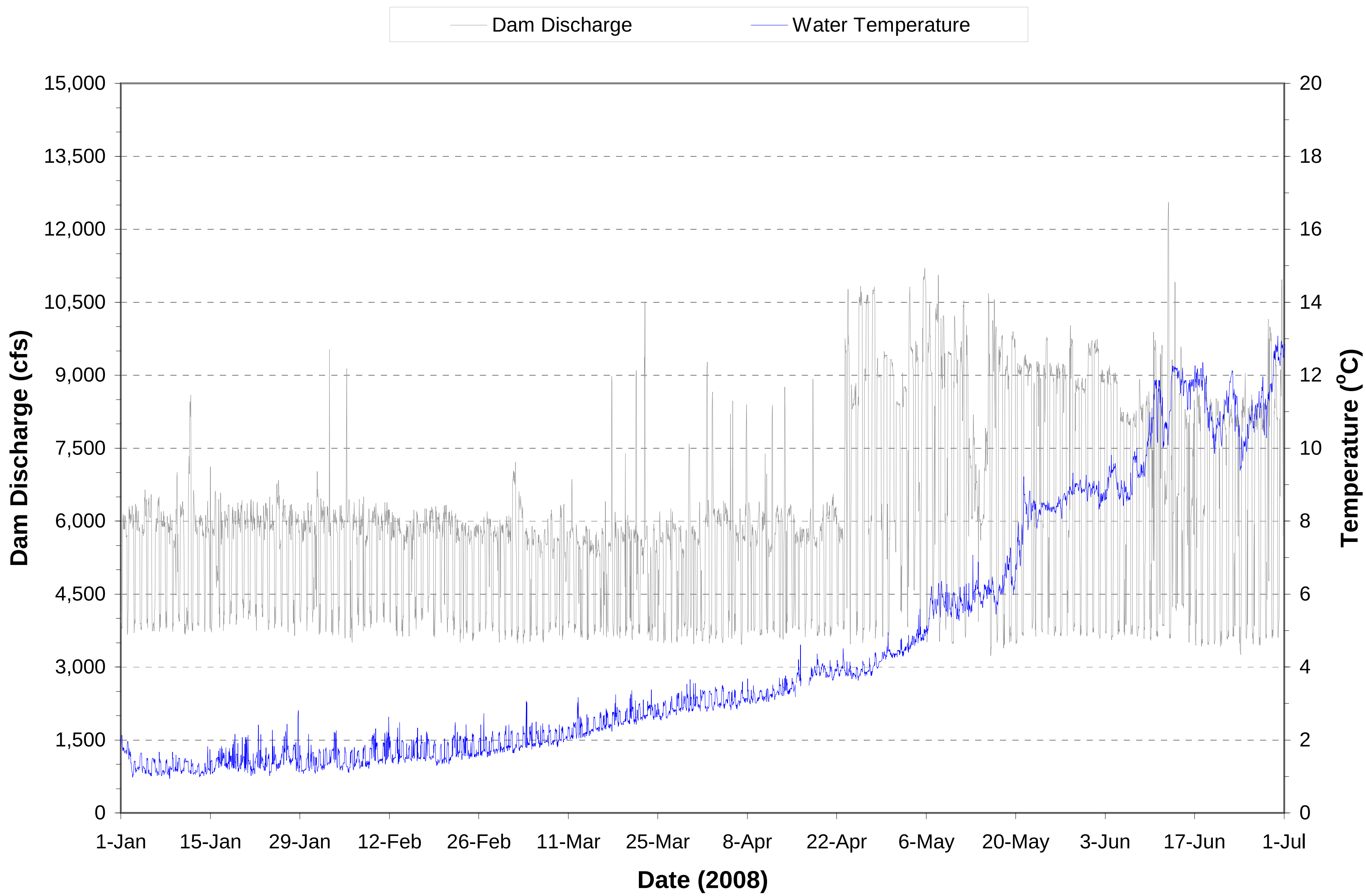


Plate 39. Hourly discharge and water temperature monitored at the Fort Peck powerplant on water discharged through the dam during the period January through June 2008.

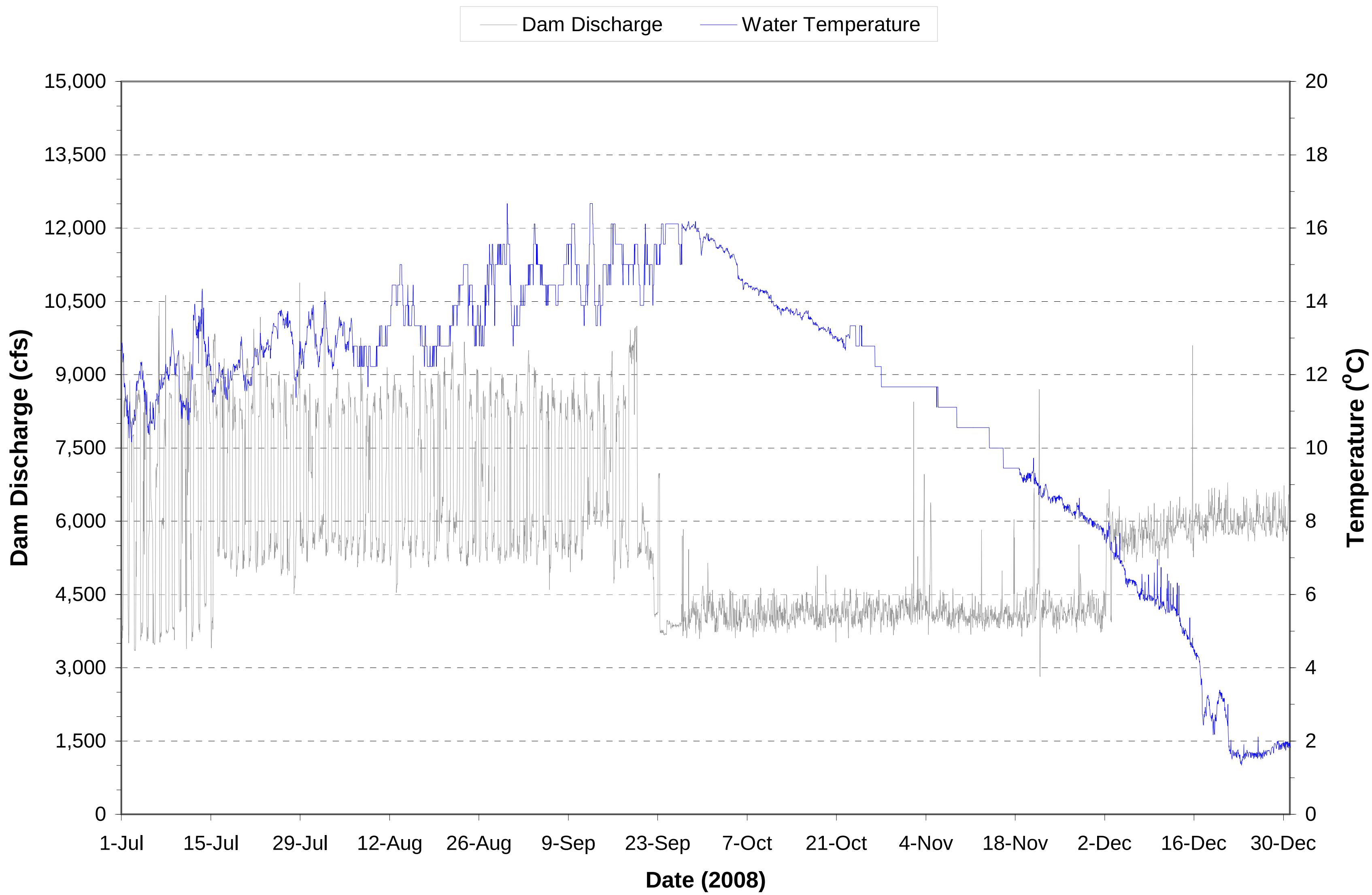


Plate 40. Hourly discharge and water temperature monitored at the Fort Peck powerplant on water discharged through the dam during the period July through December 2008.

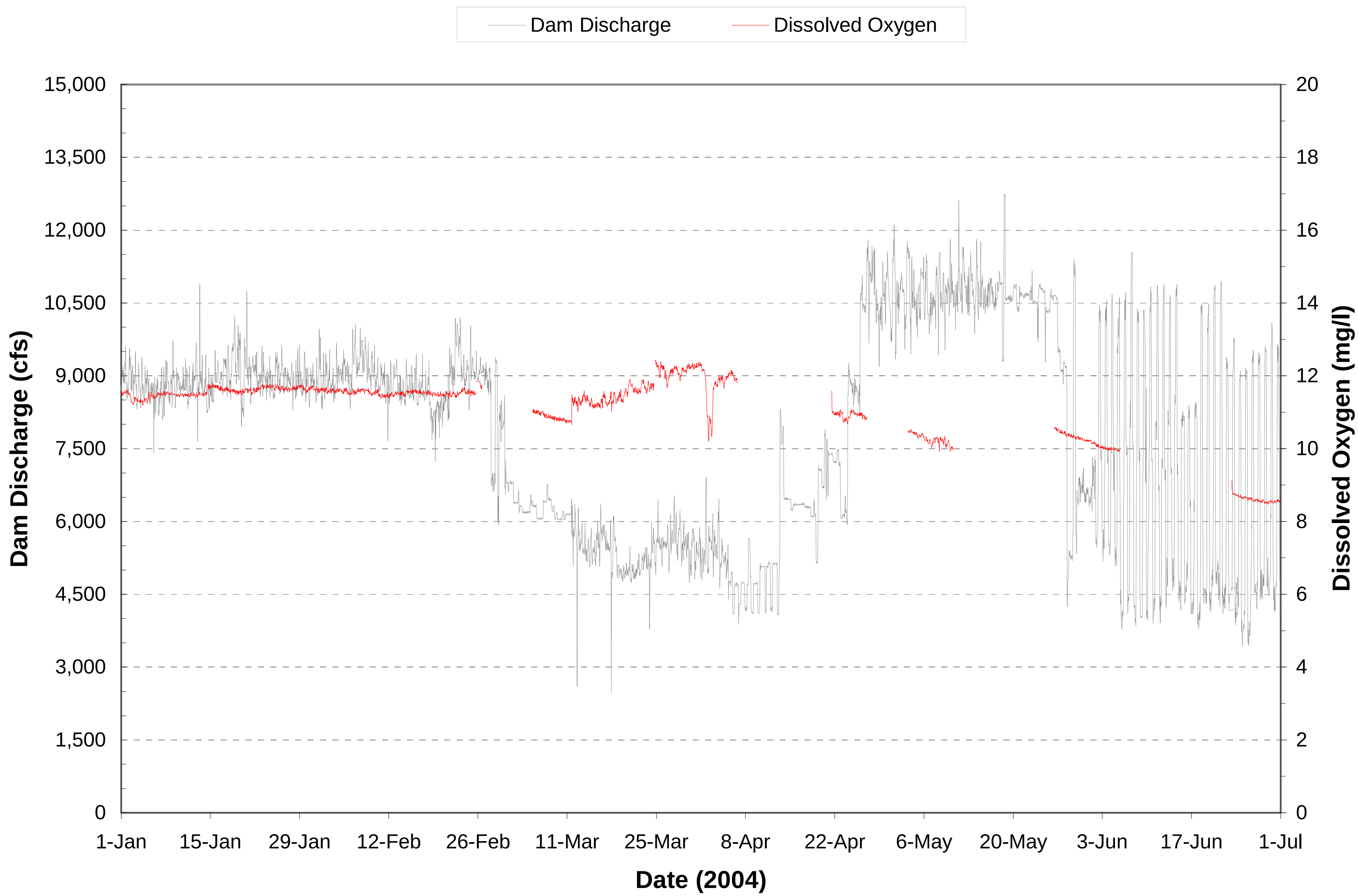


Plate 41. Hourly discharge and dissolved oxygen monitored at the Fort Peck powerplant on water discharged through the dam during the period January through June 2004.
(Note: Gaps in dissolved oxygen plot represent periods when monitoring equipment was not operational.)

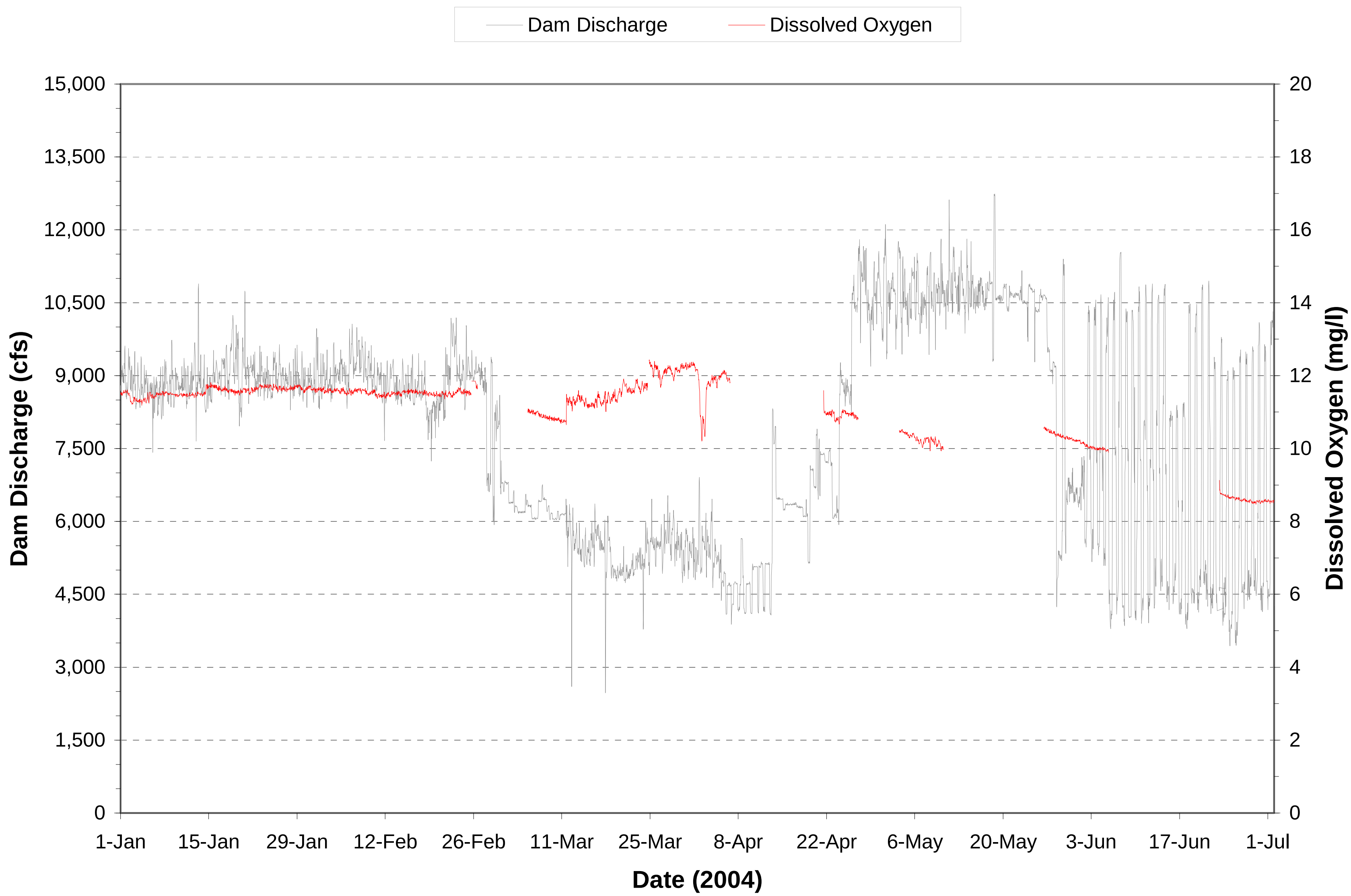


Plate 42. Hourly discharge and dissolved oxygen monitored at the Fort Peck powerplant on water discharged through the dam during the period July and December 2004.
(Note: Gaps in dissolved oxygen plot represent periods when monitoring equipment was not operational.)

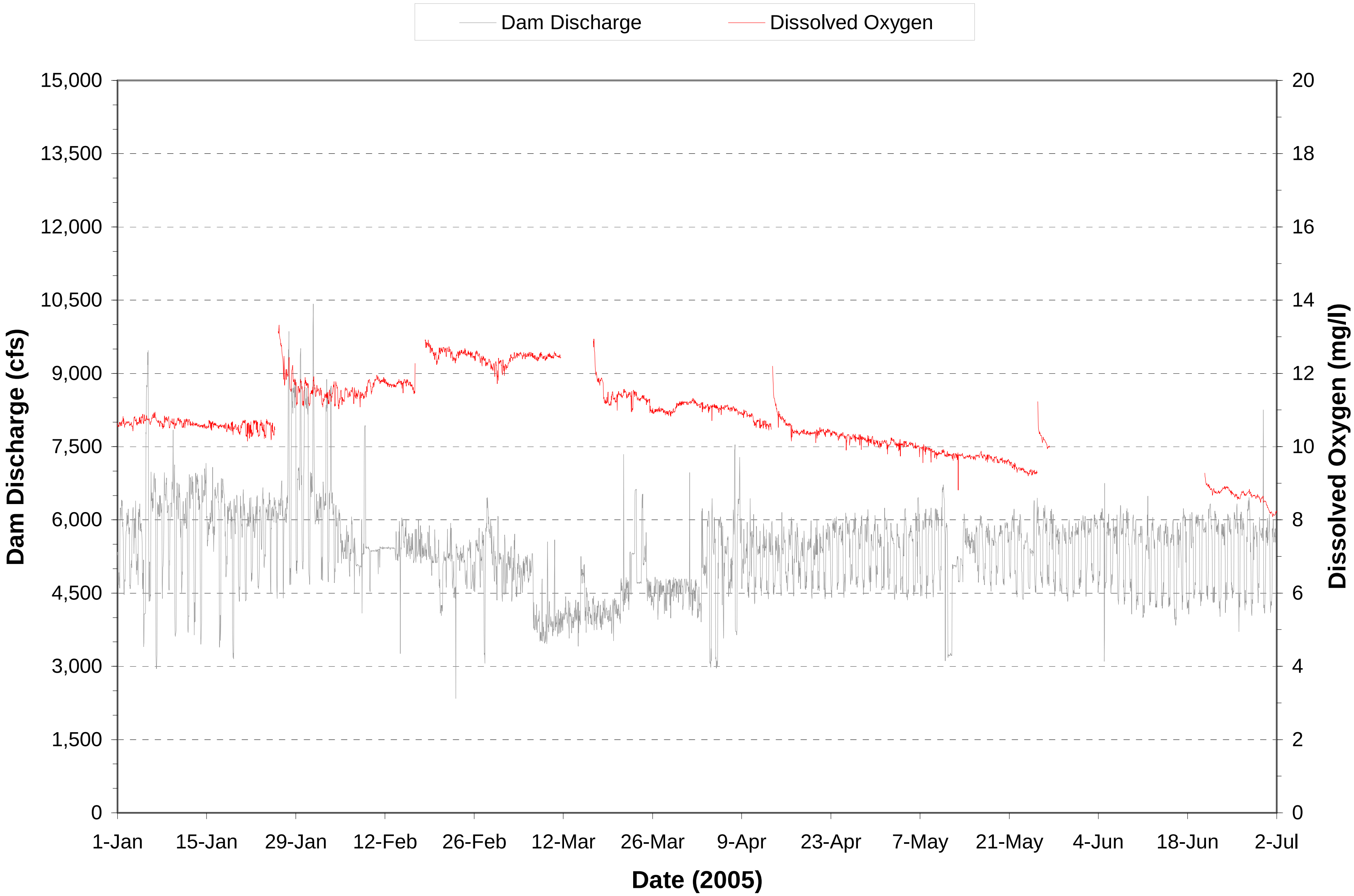


Plate 43. Hourly discharge and dissolved oxygen monitored at the Fort Peck powerplant on water discharged through the dam during the period January through June 2005.
(Note: Gaps in dissolved oxygen plot represent periods when monitoring equipment was not operational.)

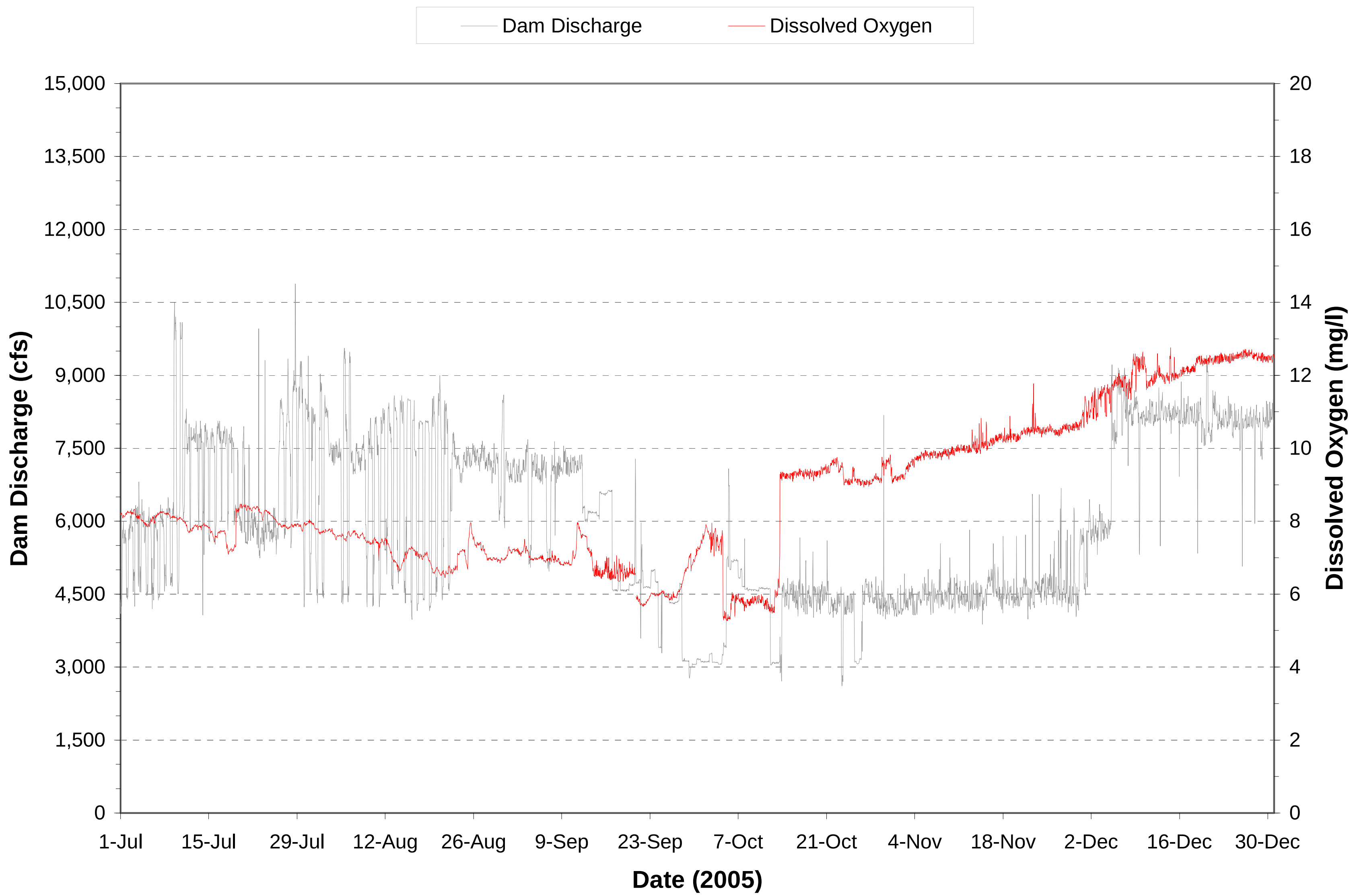


Plate 44. Hourly discharge and dissolved oxygen monitored at the Fort Peck powerplant on water discharged through the dam during the period July through December 2005.

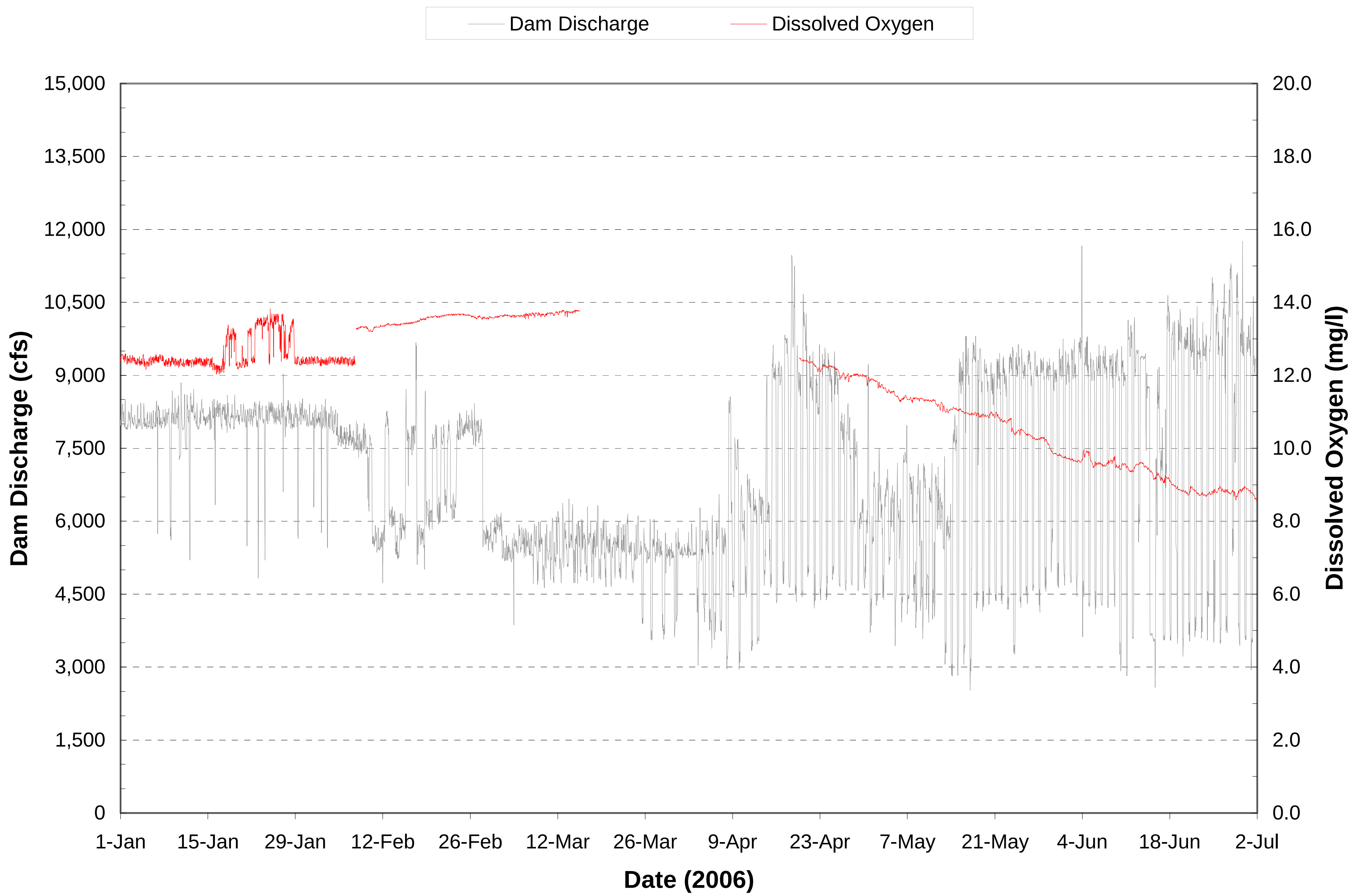


Plate 45. Hourly discharge and dissolved oxygen monitored at the Fort Peck powerplant on water discharged through the dam during the period January through June 2006.
(Note: Gaps in dissolved oxygen plot represent periods when monitoring equipment was not operational.)

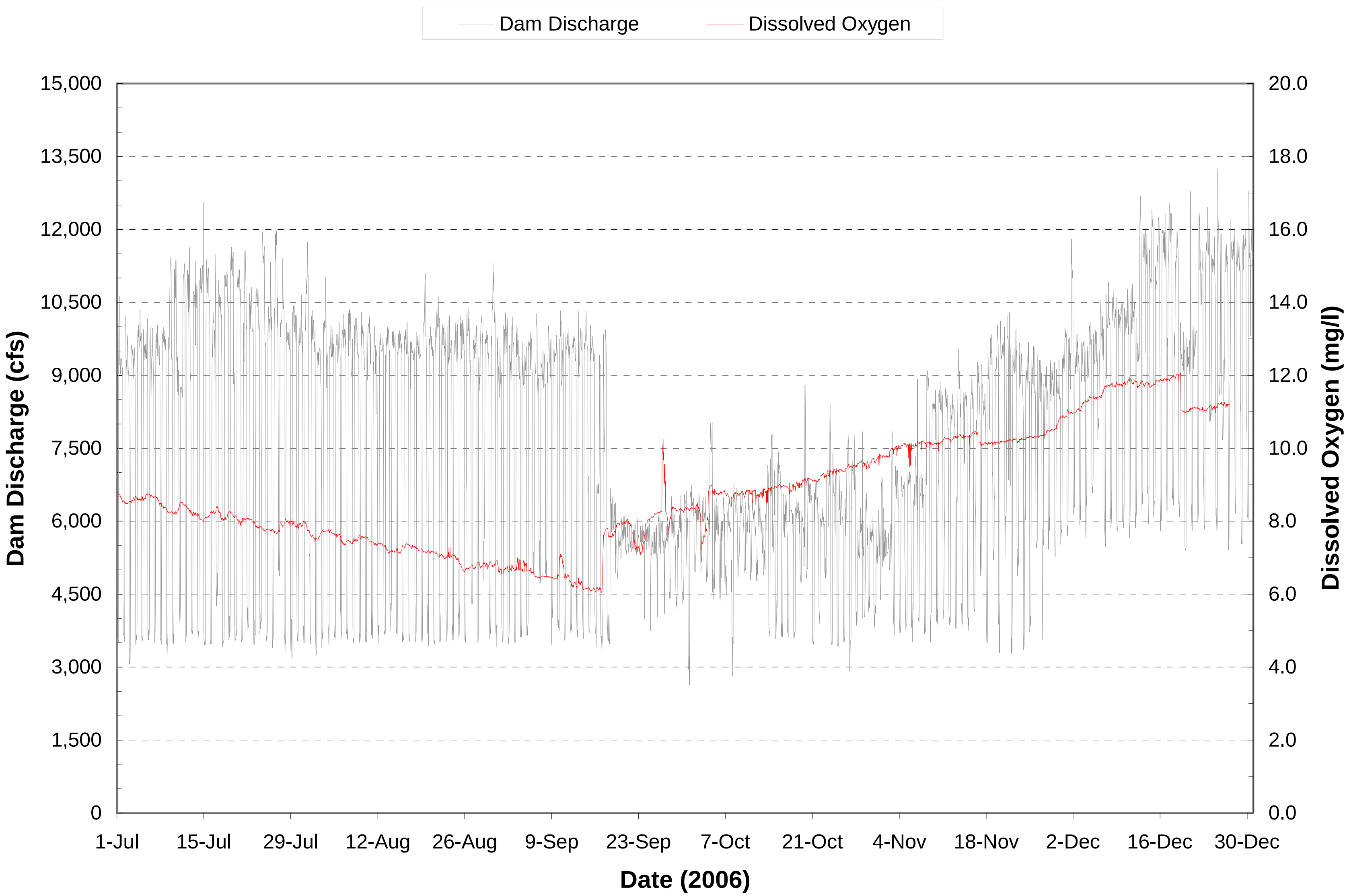


Plate 46. Hourly discharge and dissolved oxygen monitored at the Fort Peck powerplant on water discharged through the dam during the period July through December 2006.

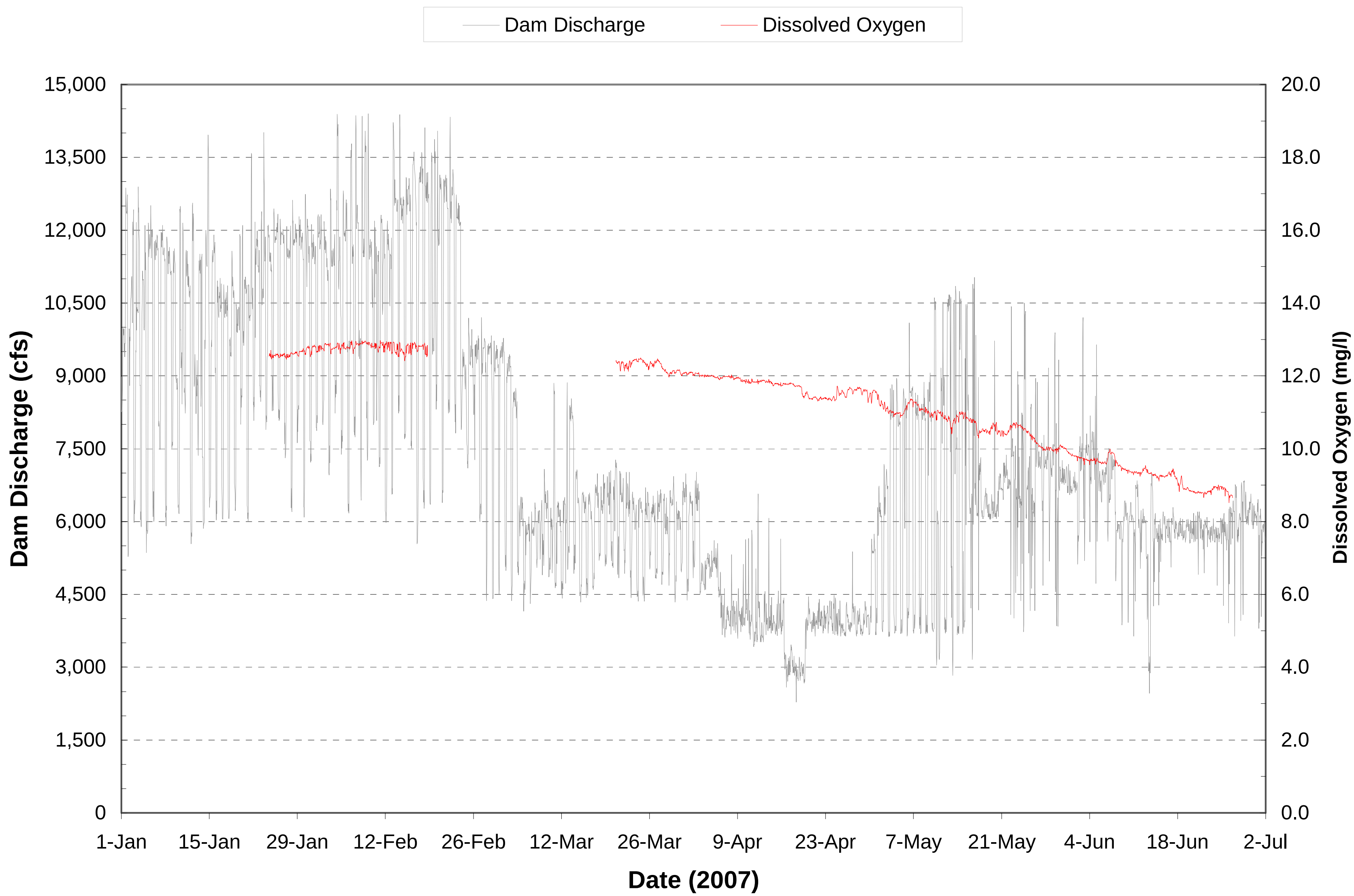


Plate 47. Hourly discharge and dissolved oxygen monitored at the Fort Peck powerplant on water discharged through the dam during the period January through June 2007.
(Note: Gaps in dissolved oxygen plot represent periods when monitoring equipment was not operational.)

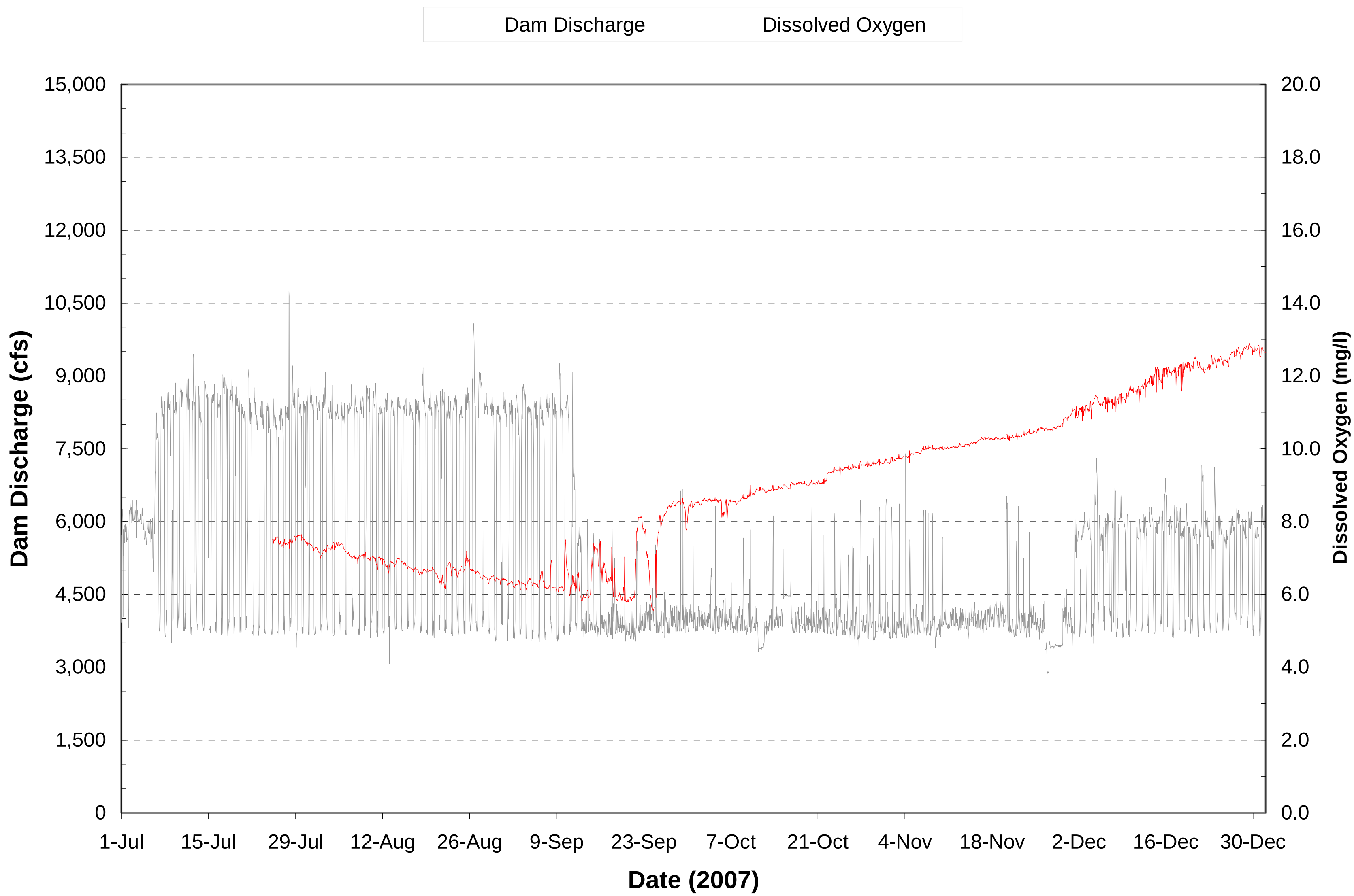


Plate 48. Hourly discharge and dissolved oxygen monitored at the Fort Peck powerplant on water discharged through the dam during the period July through December 2007.
(Note: Gaps in dissolved oxygen plot represent periods when monitoring equipment was not operational.)

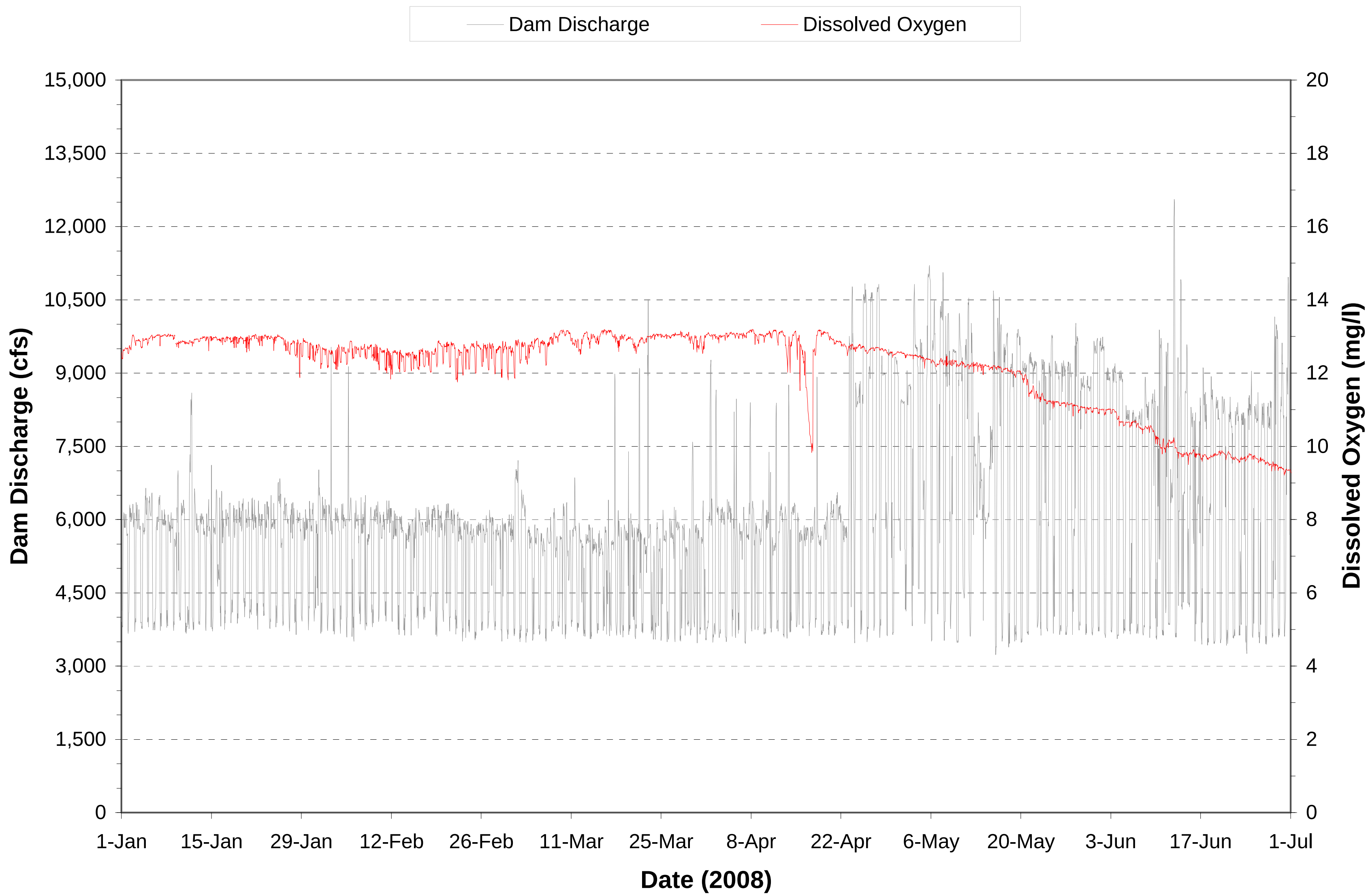


Plate 49. Hourly discharge and dissolved oxygen monitored at the Fort Peck powerplant on water discharged through the dam during the period January through June 2008.

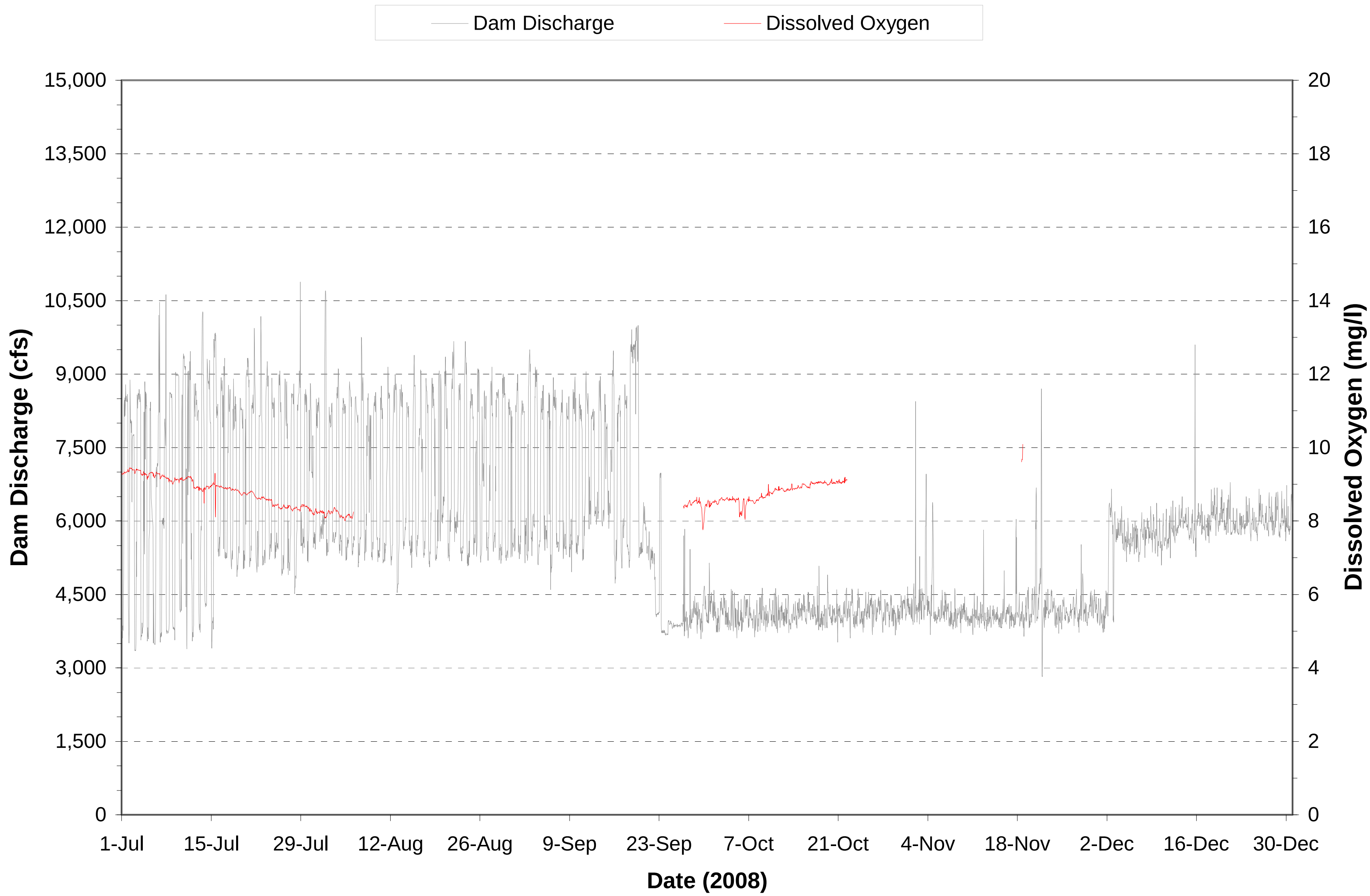


Plate 50. Hourly discharge and dissolved oxygen monitored at the Fort Peck powerplant on water discharged through the dam during the period July through December 2008.
(Note: Gaps in dissolved oxygen plot represent periods when monitoring equipment was not operational.)

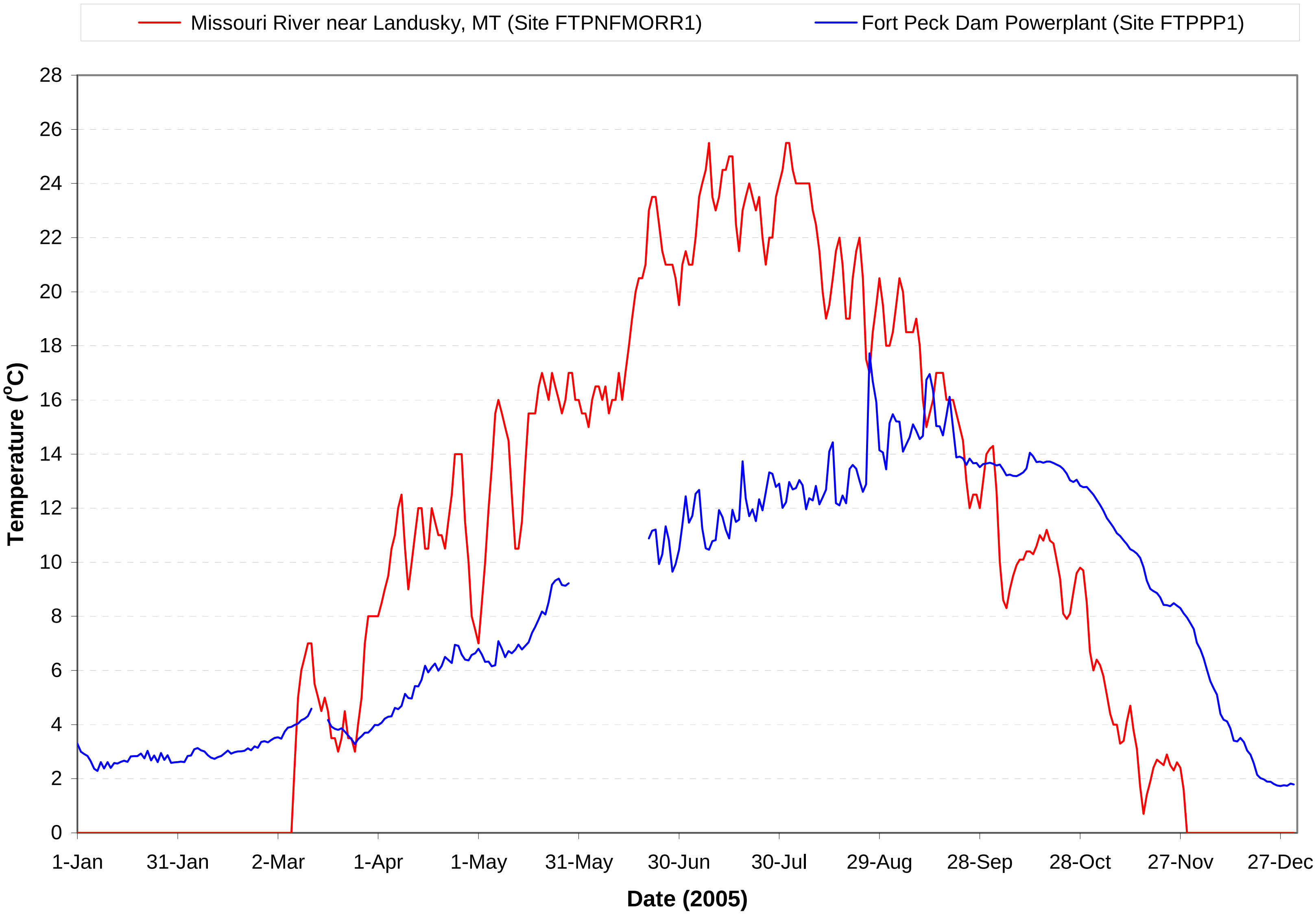


Plate 51. Mean daily water temperatures monitored at the Fort Peck Powerplant (i.e., site FTPPP1) and the Missouri River near Landusky, Montana (i.e., site FTPNFMORR1) during 2005.
(Note: Gaps in temperature plots are periods when monitoring equipment was not operational.)

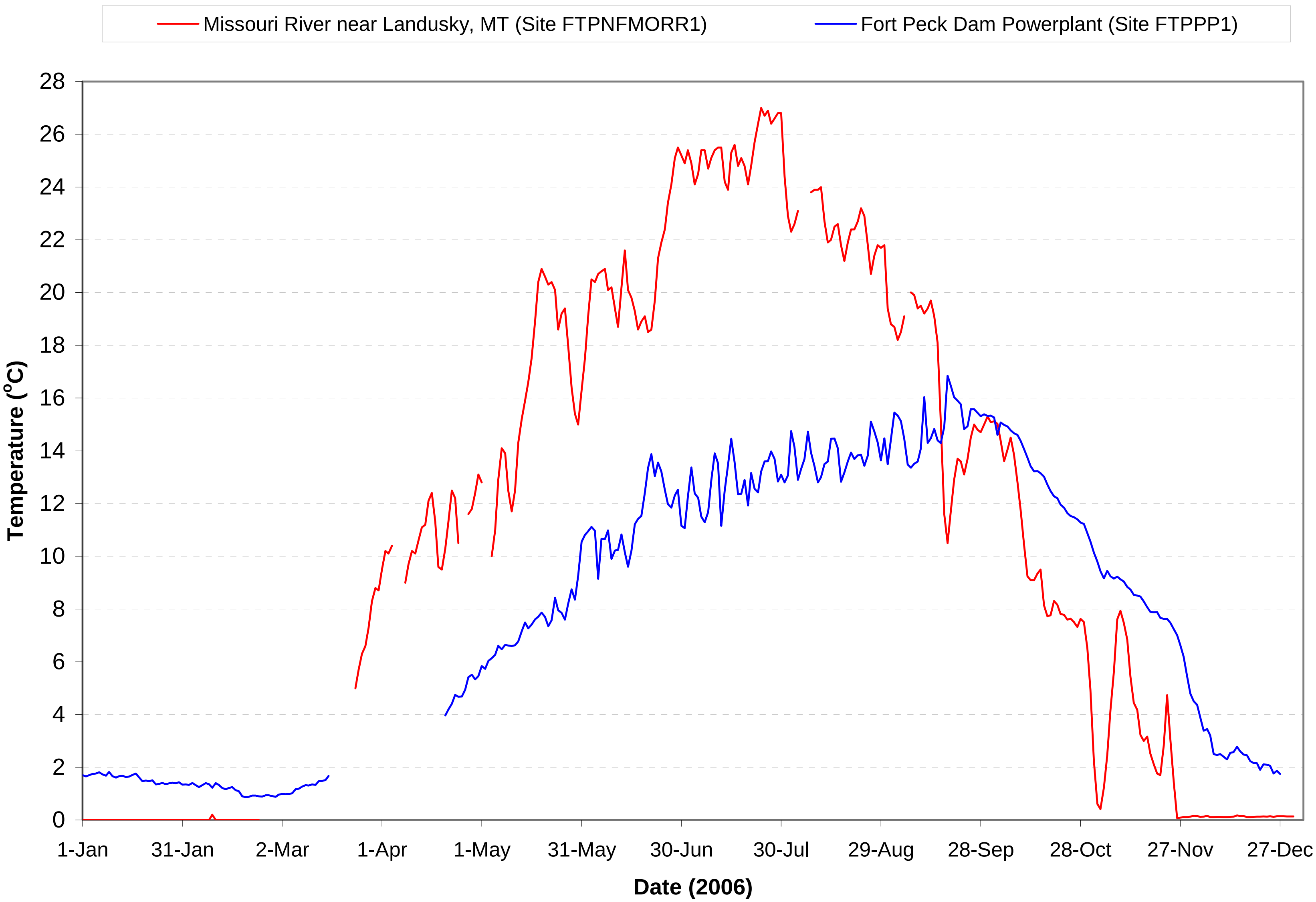


Plate 52. Mean daily water temperatures monitored at the Fort Peck Powerplant (i.e., site FTPPP1) and the Missouri River near Landusky, Montana (i.e., site FTPNFMORR1) during 2006.
(Note: Gaps in temperature plots are periods when monitoring equipment was not operational.)

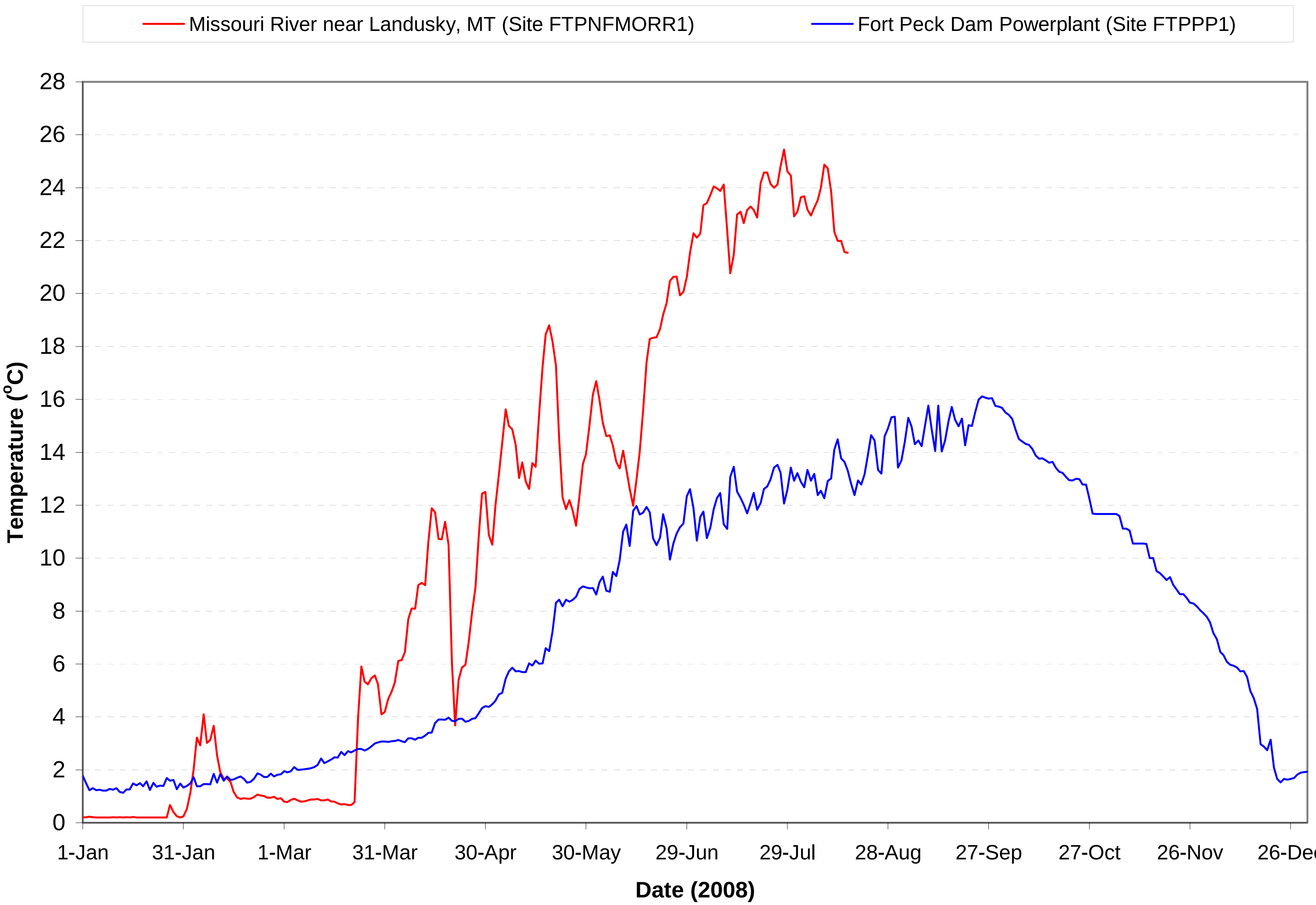


Plate 53. Mean daily water temperatures monitored at the Fort Peck Powerplant (i.e., site FTPPP1) and the Missouri River near Landusky, Montana (i.e., site FTPNFMORR1) during 2008.
(Note: Gaps in temperature plots are periods when monitoring equipment was not operational.)

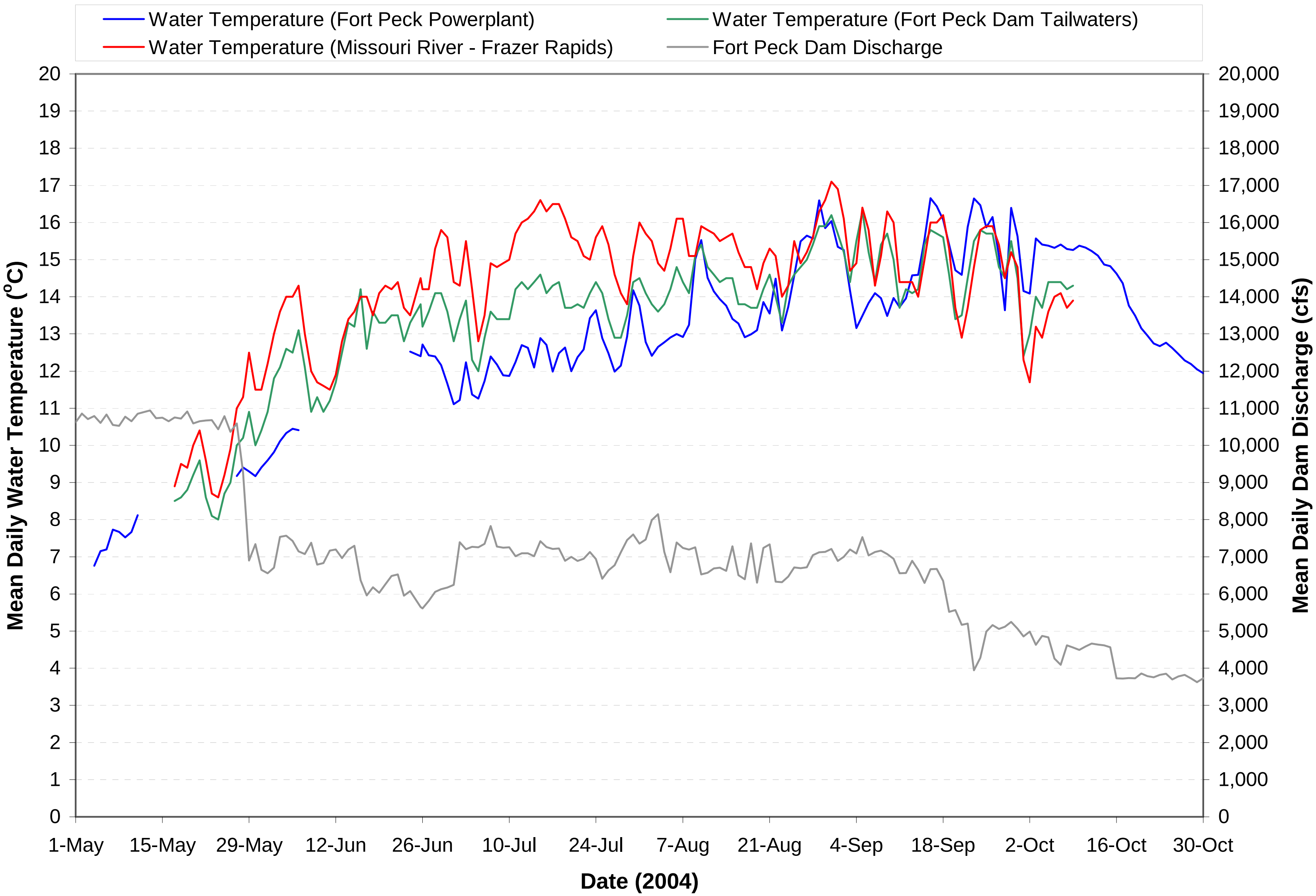


Plate 54. Mean daily water temperature monitored at the Fort Peck powerplant, Missouri River tailwaters, and Missouri River Frazer Rapids and the mean daily discharge of Fort Peck Dam from May through October during 2004**.**

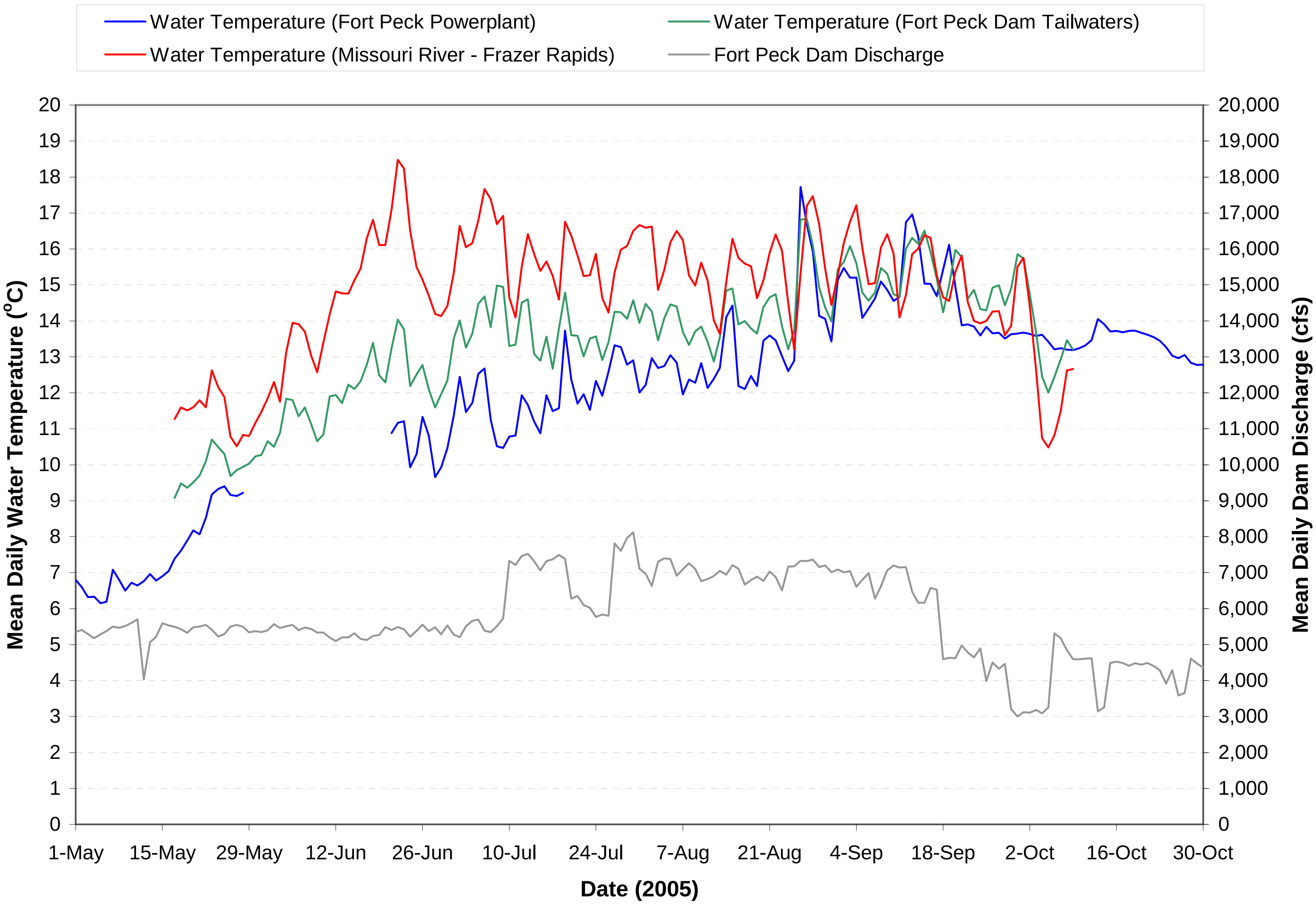


Plate 55. Mean daily water temperature monitored at the Fort Peck powerplant, Missouri River tailwaters, and Missouri River Frazer Rapids and the mean daily discharge of Fort Peck Dam from May through October during 2005**.**

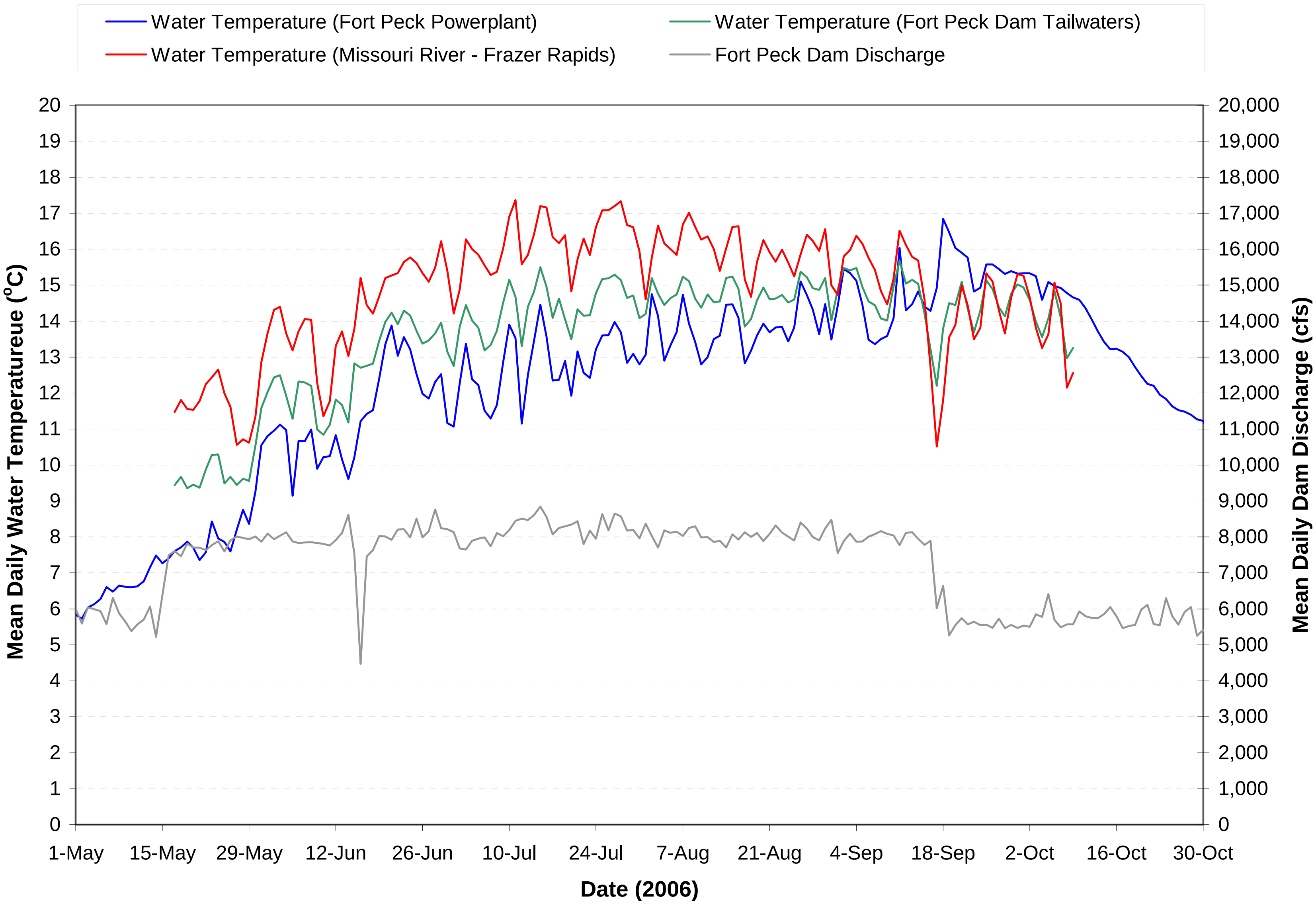


Plate 56. Mean daily water temperature monitored at the Fort Peck powerplant, Missouri River tailwaters, and Missouri River Frazer Rapids and the mean daily discharge of Fort Peck Dam from May through October during 2006.

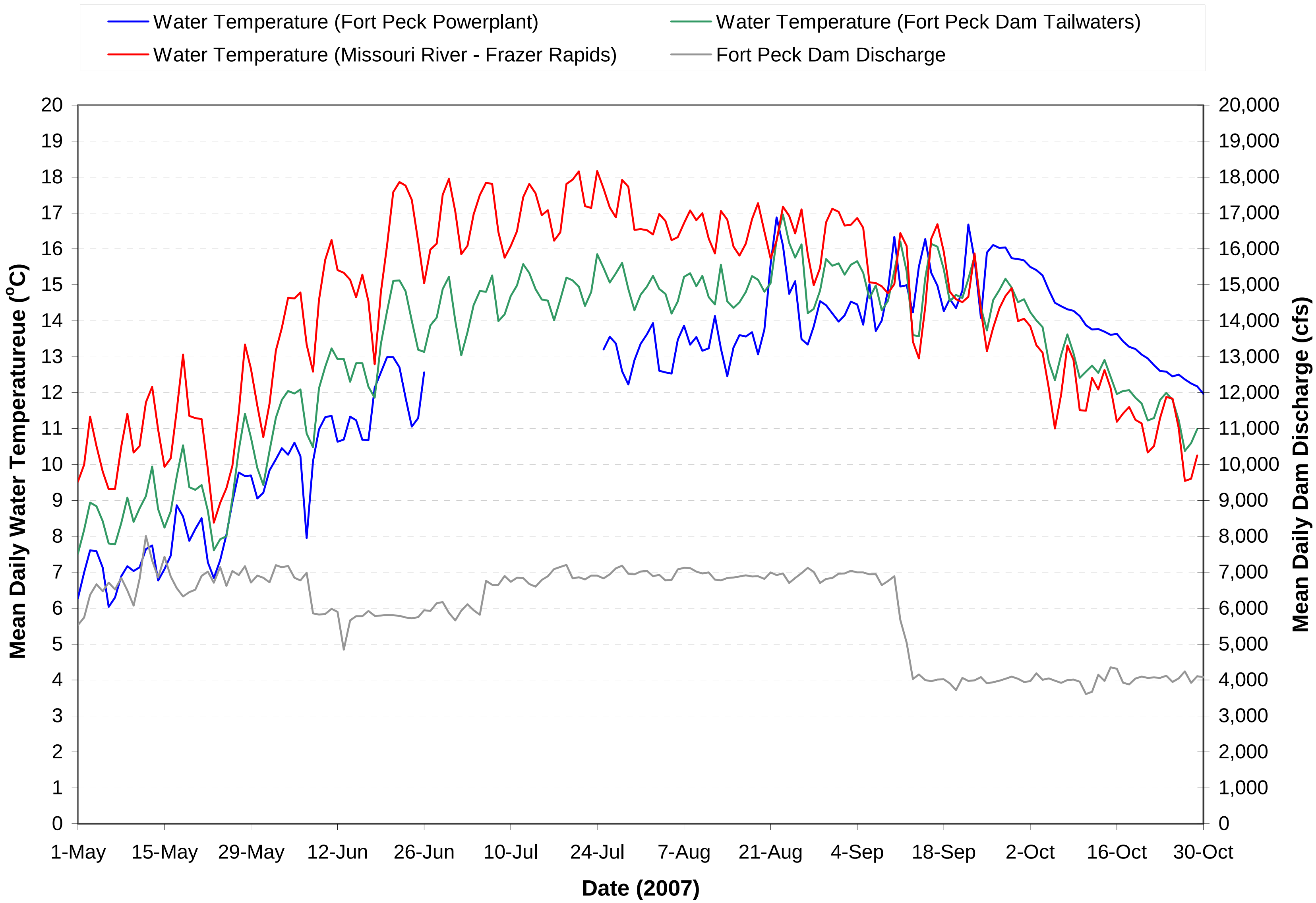


Plate 57. Mean daily water temperature monitored at the Fort Peck powerplant, Missouri River tailwaters, and Missouri River Frazer Rapids and the mean daily discharge of Fort Peck Dam from May through October during 2007.

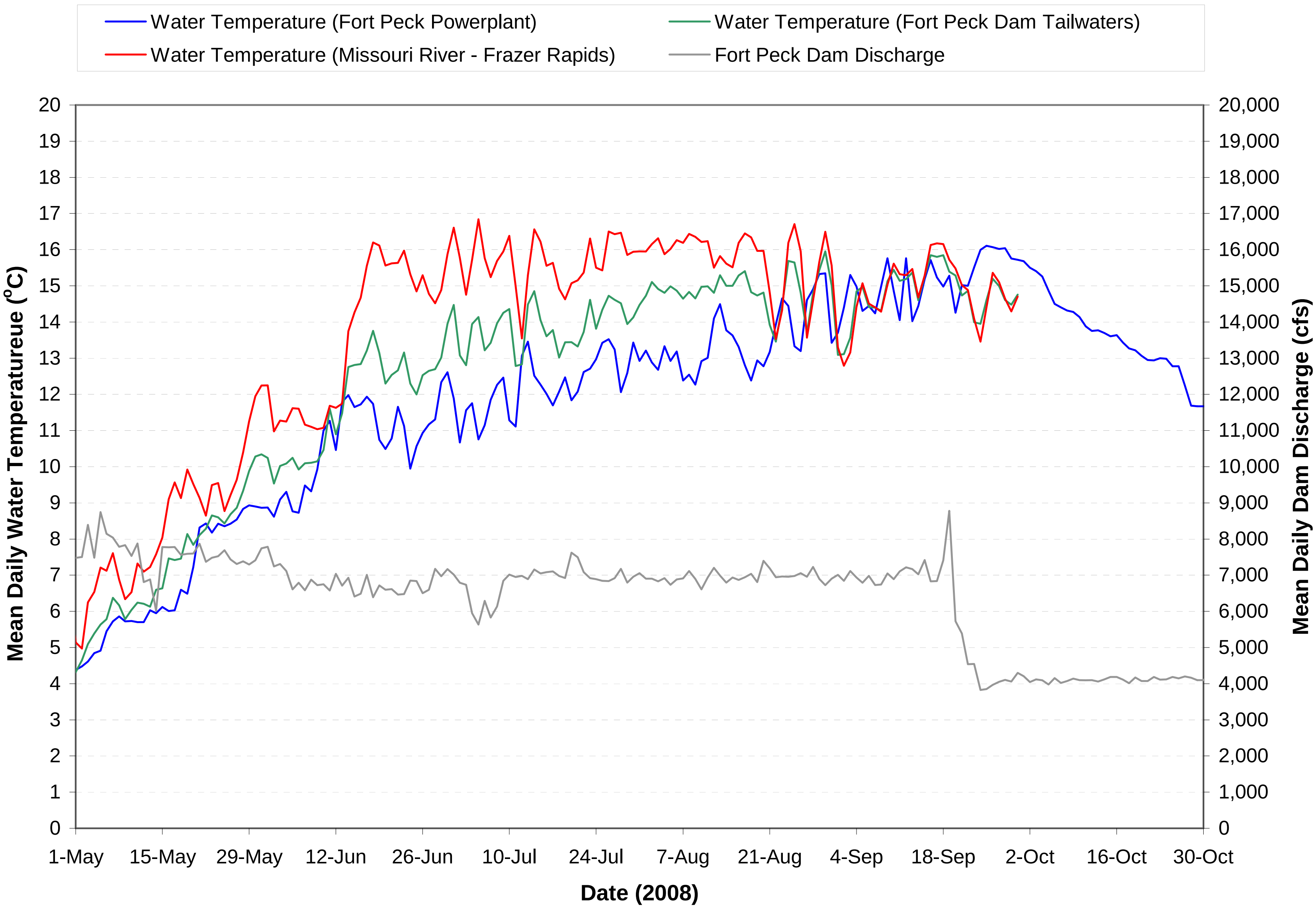


Plate 58. Mean daily water temperature monitored at the Fort Peck powerplant, Missouri River tailwaters, and Missouri River Frazer Rapids and the mean daily discharge of Fort Peck Dam from May through October during 2008.

Plate 59. Summary of monthly (May through September) water quality conditions monitored in Garrison Reservoir near Garrison Dam (Site GARLK1390A) during the 5-year period 2004 through 2008.

	Monitoring Results[A]						Water Quality Standards Attainment		
Parameter	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0 1	27	1815.0	1814 9	1807.3	1825.8	-----	-----	-----
Water Temperature (C)	0 1	1,116	13.8	14 5	4.7	23.4	29.4[1,3]	0	0%
Hypolimnion Water Temperature (C)[E]	0 1	305	12.4	12 5	8.5	17.3	15.0[2,3]	25	8%
Dissolved Oxygen (mg/l)	0 1	1,116	8.6	8.6	3.8	11.8	5[1,4]	46	4%
Dissolved Oxygen (% Sat.)	0 1	1,040	86.1	91.2	37.6	114.2	-----	-----	-----
Hypolimnion Dissolved Oxygen (mg/l)[E]	0 1	305	7.3	7.6	3.8	10.4	5[1,4]	45	15%
Specific Conductance (umho/cm)	1	1,040	599	607	487	656	-----	-----	-----
pH (S.U.)	0 1	1,040	8.3	8 3	7.3	8.9	7.0[1,4], 9.0[1,3]	0	0%
Turbidity (NTUs)	1	1,040	5	3	n.d.	62	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	1,040	381	383	243	538	-----	-----	-----
Secchi Depth (in.)	1	25	109	98	36	216	-----	-----	-----
Alkalinity, Total (mg/l)	7	53	162	161	140	180	-----	-----	-----
Ammonia, Total (mg/l)	0.02	55	-----	0.03	n.d.	0.33	3.2[1,3,5], 1.4[1,5,6]	0	0%
Carbon, Total Organic (mg/l)	0.05	51	2.9	2 9	1.3	4.0	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	34	10	9	n.d.	28	-----	-----	-----
Chloride (mg/l)	1	32	9	9	7	11	100[1,3]	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	1,035	-----	1	n.d.	32	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	25	-----	1	n.d.	16	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	42	436	430	376	510	-----	-----	-----
Iron, Total (ug/l)	40	33	165	129	40	810	-----	-----	-----
Kjeldahl N, Total (mg/l)	0 1	55	0.3	0 3	n.d.	1.3	-----	-----	-----
Manganese, Total (ug/l)	2	34	10	8	n.d.	40	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	55	0.07	0.07	n.d.	0.18	1.0[1,3], 0 25[7]	0	0%
Phosphorus, Dissolved (mg/l)	0.02	55	-----	0.02	n.d.	0.08	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	55	0.05	0.03	n.d.	0.41	0.02[7]	32	58%
Phosphorus-Ortho, Dissolved (mg/l)	0.02	55	-----	n.d.	n.d.	0.11	-----	-----	-----
Sulfate (mg/l)	1	51	164	164	140	180	250[1,3]	0	0%
Suspended Solids, Total (mg/l)	4	55	-----	n.d.	n.d.	12	-----	-----	-----
Microcystin, Total (ug/l)	0.2	19	-----	n.d.	n.d.	0.4	-----	-----	-----

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for Class 1 lakes.
- (2) Applies to hypolimnion of Class 1 lakes during periods of thermal stratification.
- (3) Daily maximum criterion (monitoring results directly comparable to criterion).
- (4) Daily minimum criterion (monitoring results directly comparable to criterion).
- (5) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (6) 30-day average criterion (monitoring results not directly comparable to criterion).
- (7) Nutrient guideline for lake or reservoir improvement or management.

(E) The top of the hypolimnion is generally defined as the depth where a temperature drop of at least 0 5 C last occurs over a 1-meter depth increment.

Plate 60. Summary of monthly (June through September) water quality conditions monitored in Garrison Reservoir near Douglas Bay (site GARLK1399DW) during the 4-year period 2004 through 2007.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Resolution Limit	No. of Obs.	Mean[B]	Median	Min.	Max.	State WQS Criteria[C]	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0 1	8	1814.4	1814.6	1810.1	1817.0	-----	-----	-----
Water Temperature (C)	0 1	309	15 9	17.1	8.7	21.1	29.4[1,3]	0	0%
Hypolimnion Water Temperature (C)[D]	0 1	75	12.7	12.8	8.7	15.1	15.0[2,3]	1	1%
Dissolved Oxygen (mg/l)	0 1	309	7.6	8.1	3.6	9.6	5[1,4]	43	14%
Dissolved Oxygen (% Sat.)	0 1	270	81.4	87.9	36.7	110.0	-----	-----	-----
Hypolimnion Dissolved Oxygen (mg/l)[D]	0 1	75	5.8	4.9	3.6	9.0	5.0[1,4]	39	52%
Specific Conductance (umho/cm)	1	270	569	564	485	643	-----	-----	-----
pH (S.U.)	0 1	270	8 2	8.3	7.2	8.7	7.0[1,4], 9.0[1,3]	0	0%
Turbidity (NTUs)	1	270	6	4	n.d.	36	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	270	424	417	348	511	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	269	1	n.d.	n.d.	11	-----	-----	-----
Secchi Depth (in)	1	5	120	108	60	180	-----	-----	-----

n.d. = Not detected.

(A) Results for all parameters except Pool Elevation and Secchi Depth are for water column depth-profile measurements.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e , log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

(1) Criteria for Class 1 lakes.

(2) Applies to hypolimnion of Class 1 lakes during periods of thermal stratification.

(3) Daily maximum criterion (monitoring results directly comparable to criterion).

(4) Daily minimum criterion (monitoring results directly comparable to criterion).

(D) The top of the hypolimnion is generally defined as the depth where a temperature drop of at least 0.5 C last occurs over a 1-meter depth increment.

Plate 61. Summary of monthly (May through September) water quality conditions monitored in Garrison Reservoir near Beulah Bay (Site GARLK1412DW) during the 5-year period 2004 through 2008.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	26	1815 3	1815.0	1807.4	1825.9	-----	-----	-----
Water Temperature (C)	0.1	888	15 1	15.5	5.0	23.3	29.4[1,3]	0	0%
Hypolimnion Water Temperature (C)[E]		205	12.4	13.3	6.7	16.6	15.0[2,3]	28	14%
Dissolved Oxygen (mg/l)	0.1	888	8 3	8.3	2.8	11.8	5[1,4]	72	8%
Dissolved Oxygen (% Sat.)	0.1	822	84.6	90.0	28.3	107.7	-----	-----	-----
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	205	6.8	7.0	2.8	10.7	5[1,4]	65	32%
Specific Conductance (umho/cm)	1	822	594	598	458	655	-----	-----	-----
pH (S.U.)	0.1	822	8 3	8.4	7.3	9.0	7.0[1,4], 9.0[1,4]	0	0%
Turbidity (NTUs)	1	823	5	3	n.d.	38	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	822	388	378	265	535	-----	-----	-----
Secchi Depth (in.)	1	24	101	108	37	144	-----	-----	-----
Alkalinity, Total (mg/l)	7	51	160	161	130	180	-----	-----	-----
Ammonia, Total (mg/l)	0.02	51	-----	0.03	n.d.	0 26	2.6[1,3,5], 1.1[1,5,6]	0	0%
Carbon, Total Organic (mg/l)	0.05	49	2 9	3.0	1.2	4.3	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	30	12	11	n.d.	61	-----	-----	-----
Chloride (mg/l)	1	30	9	9	8	11	100[1,3]	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	821	-----	1	n.d.	10	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	18	3	3	1	7	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	51	434	420	350	613	-----	-----	-----
Iron, Total (ug/l)	40	29	232	110	50	2,380	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	51	0 3	0.3	n.d.	1.0	-----	-----	-----
Manganese, Total (ug/l)	2	29	15	8	n.d.	60	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	51	-----	0.06	n.d.	0.20	1.0[1,3], 0.25[7]	0	0%
Phosphorus, Dissolved (mg/l)	0.02	51	-----	0.02	n.d.	0.27	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	51	0.04	0.03	n.d.	0 33	0.02[7]	28	55%
Phosphorus-Ortho, Dissolved (mg/l)	0.02	51	-----	n.d.	n.d.	0.03	-----	-----	-----
Sulfate (mg/l)	1	51	164	168	120	180	250[1,3]	0	0%
Suspended Solids, Total (mg/l)	4	51	-----	n.d.	n.d.	11	-----	-----	-----
Microcystin, Total (ug/l)	0.2	16	-----	n.d.	n.d.	0.4	-----	-----	-----

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for Class 1 lakes.
- (2) Applies to hypolimnion of Class 1 lakes during periods of thermal stratification.
- (3) Daily maximum criterion (monitoring results directly comparable to criterion).
- (4) Daily minimum criterion (monitoring results directly comparable to criterion).
- (5) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (6) 30-day average criterion (monitoring results not directly comparable to criterion).
- (7) Nutrient guideline for lake or reservoir improvement or management.

(E) The top of the hypolimnion is generally defined as the depth where a temperature drop of at least 0.5 C last occurs over a 1-meter depth increment.

Plate 62. Summary of monthly (June through September) water quality conditions monitored in Garrison Reservoir near Indian Hills (site GARLK1428DW) during 2004.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Resolution Limit	No. of Obs.	Mean[B]	Median	Min.	Max.	State WQS Criteria[C]	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	5	1815.2	1815.2	1813.4	1817.0	-----	-----	-----
Water Temperature (C)	0.1	136	15.9	16 9	10.6	22.9	29.4[1,3]	0	0%
Hypolimnion Water Temperature (C)[D]	0.1	17	11.7	11 2	10.6	14.4	15.0[2,3]	0	0%
Dissolved Oxygen (mg/l)	0.1	136	7.8	7 9	4.4	10.7	5[1,4]	6	4%
Dissolved Oxygen (% Sat.)	0.1	136	84.2	85.3	47.3	112.4	-----	-----	-----
Hypolimnion Dissolved Oxygen (mg/l)[D]	0.1	17	7.1	6 9	4.6	8.6	5[1,4]	3	18%
Specific Conductance (umho/cm)	1	136	538	544	487	569	-----	-----	-----
pH (S.U.)	0.1	136	8.2	8.3	7.5	8.5	7.0[1,4], 9.0[1,3]	0	0%
Turbidity (NTUs)	1	136	6	4	1	23	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	136	422	415	386	483	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	136	1	n.d.	n.d.	9	-----	-----	-----
Secchi Depth (in)	1	4	123	120	72	180	-----	-----	-----

n.d. = Not detected.

(A) Results for all parameters except Pool Elevation and Secchi Depth are for water column depth-profile measurements.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e , log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for Class 1 lakes.
- (2) Applies to hypolimnion of Class 1 lakes during periods of thermal stratification.
- (3) Daily maximum criterion (monitoring results directly comparable to criterion).
- (4) Daily minimum criterion (monitoring results directly comparable to criterion).

(D) The top of the hypolimnion is generally defined as the depth where a temperature drop of at least 0.5 C last occurs over a 1-meter depth increment.

Plate 63. Summary of monthly (May through September) water quality conditions monitored in Garrison Reservoir near Deepwater Bay (Site GARLK1445DW) during the 5-year period 2004 through 2008.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	26	1815.3	1815.0	1807.5	1825.8	-----	-----	-----
Water Temperature (C)	0 1	682	16.3	16.7	5.7	24.8	29.4[1,3]	0	0%
Hypolimnion Water Temperature (C)[E]	0 1	158	13.1	12.9	8.5	17.1	15.0[2,3]	42	27%
Dissolved Oxygen (mg/l)	0.1	682	7.8	8.0	1.0	11.7	5[1,4]	61	9%
Dissolved Oxygen (% Sat.)	0 1	634	81.9	87.3	10.0	112.0	-----	-----	-----
Hypolimnion Dissolved Oxygen (mg/l)[E]	0 1	158	6.3	7.1	1.0	9.8	5[1,4]	50	32%
Specific Conductance (umho/cm)	1	634	550	549	3	672	-----	-----	-----
pH (S.U.)	0 1	608	8.3	8.3	7.2	9.0	7.0[1,4], 9.0[1,4]	0	0%
Turbidity (NTUs)	1	633	10	7	n.d.	58	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	634	364	363	139	492	-----	-----	-----
Secchi Depth (in.)	1	23	71	72	24	148	-----	-----	-----
Alkalinity, Total (mg/l)	7	48	146	147	89	180	-----	-----	-----
Ammonia, Total (mg/l)	0.02	48	-----	0.03	n.d.	0 26	3 2[1,3,5], 1.3[1,5,6]	0	0%
Carbon, Total Organic (mg/l)	0.05	46	3.0	3.1	n.d.	4.6	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	30	13	11	n.d.	58	-----	-----	-----
Chloride (mg/l)	1	30	9	8	6	12	100[1,3]	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	625	-----	2	n.d.	24	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	22	4	3	n.d.	16	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	48	405	396	280	582	-----	-----	-----
Iron, Total (ug/l)	40	28	327	339	70	651	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	48	0.3	0.3	n.d.	0.7	-----	-----	-----
Manganese, Total (ug/l)	2	28	48	40	n.d.	133	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	48	-----	0.08	n.d.	0.30	1.0[1,3], 0.25[7]	0, 1	0%, 2%
Phosphorus, Dissolved (mg/l)	0.02	48	-----	0.02	n.d.	0.08	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	48	0.04	0.03	n.d.	0 32	0.02[7]	34	71%
Phosphorus-Ortho, Dissolved (mg/l)	0.02	48	-----	n.d.	n.d.	0.07	-----	-----	-----
Sulfate (mg/l)	1	48	153	150	118	190	250[1,3]	0	0%
Suspended Solids, Total (mg/l)	4	48	-----	2	n.d.	16	-----	-----	-----
Microcystin, Total (ug/l)	0.2	17	-----	n.d.	n.d.	0.2	-----	-----	-----

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for Class 1 lakes.
- (2) Applies to hypolimnion of Class 1 lakes during periods of thermal stratification.
- (3) Daily maximum criterion (monitoring results directly comparable to criterion).
- (4) Daily minimum criterion (monitoring results directly comparable to criterion).
- (5) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (6) 30-day average criterion (monitoring results not directly comparable to criterion).
- (7) Nutrient guideline for lake or reservoir improvement or management.

(E) The top of the hypolimnion is generally defined as the depth where a temperature drop of at least 0.5 C last occurs over a 1-meter depth increment.

Plate 64. Summary of monthly (June through September) water quality conditions monitored in Garrison Reservoir near Independence Point (site GARLK1454DW) during 2004.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Resolution Limit	No. of Obs.	Mean[B]	Median	Min.	Max.	State WQS Criteria[C]	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	5	1815.2	1815 2	1813.4	1817.0	-----	-----	-----
Water Temperature (C)	0.1	109	16.6	16.8	11.1	23.8	29.4[1,3]	0	0%
Hypolimnion Water Temperature (C)[D]	0.1	14	12.2	11.4	11.1	14.4	15.0[2,3]	0	0%
Dissolved Oxygen (mg/l)	0.1	109	7.5	7.6	3.9	9.8	5[1,4]	4	4%
Dissolved Oxygen (% Sat.)	0.1	109	81.7	81 3	38.8	120.6	-----	-----	-----
Hypolimnion Dissolved Oxygen (mg/l)[D]	0.1	14	6.0	6 3	3.9	7.1	5.0[1,4]	4	29%
Specific Conductance (umho/cm)	1	109	483	478	452	552	-----	-----	-----
pH (S.U.)	0.1	109	8.1	8 2	7.3	8.6	7.0[1,4], 9.0[1,3]	0	0%
Turbidity (NTUs)	1	109	13	11	4	31	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	109	412	417	365	447	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	109	2	1.	n.d.	10	-----	-----	-----
Secchi Depth (in)	1	5	56	60	36	84	-----	-----	-----

n.d. = Not detected.

(A) Results for all parameters except Pool Elevation and Secchi Depth are for water column depth-profile measurements.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for Class 1 lakes.
- (2) Applies to hypolimnion of Class 1 lakes during periods of thermal stratification.
- (3) Daily maximum criterion (monitoring results directly comparable to criterion).
- (4) Daily minimum criterion (monitoring results directly comparable to criterion).

(D) The top of the hypolimnion is generally defined as the depth where a temperature drop of at least 0.5 C last occurs over a 1-meter depth increment.

Plate 65. Summary of monthly (May through September) water quality conditions monitored in Garrison Reservoir near New Town (Site GARLK1481DW) during the 5-year period 2004 through 2008.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria***	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	25	1815.6	1815.5	1807 5	1825.9	-----	-----	-----
Water Temperature (C)	0.1	377	18.2	18.1	8 1	26.4	29.4(1,3)	0	0%
Hypolimnion Water Temperature (C)[E]	0.1	13	18.4	18.3	15.7	20.8	15.0(2,3)	13	100%
Dissolved Oxygen (mg/l)	0.1	377	8.2	8.3	4.0	11.3	5(1,4)	6	2%
Dissolved Oxygen (% Sat.)	0.1	367	89.7	92.1	44 3	117.4	-----	-----	-----
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	13	5.5	5.7	4.0	6.5	5(1,4)	3	23%
Specific Conductance (umho/cm)	1	366	497	493	339	723	-----	-----	-----
pH (S.U.)	0.1	367	8.3	8.4	7.4	8.8	7.0(1,4), 9.0(1,4)	0	0%
Turbidity (NTUs)	1	366	43	24	n.d.	360	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	367	354	336	259	466	-----	-----	-----
Secchi Depth (in.)	1	25	28	24	8	66	-----	-----	-----
Alkalinity, Total (mg/l)	7	30	133	128	79	178	-----	-----	-----
Ammonia, Total (mg/l)	0.02	30	-----	0.04	n.d.	0 28	2.6(1,3,5), 1.0(1,5,6)	0	0%
Carbon, Total Organic (mg/l)	0.05	29	3.0	2.9	1 1	5.5	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	15	8	8	n.d.	16	-----	-----	-----
Chloride (mg/l)	1	15	8	8	4	13	100(1,3)	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	364	7	4	n.d.	100	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	22	7	7	n.d.	22	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	30	364	358	240	522	-----	-----	-----
Iron, Total (ug/l)	40	13	1,112	829	133	3,556	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	30	0.4	0.4	0 1	0.8	-----	-----	-----
Manganese, Total (ug/l)	2	13	31	25	9	74	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	30	-----	0.04	n.d.	0.44	1.0(1,3), 0.25(7)	3	10%
Phosphorus, Dissolved (mg/l)	0.02	30	-----	0.02	n.d.	0.07	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	30	0.06	0.05	n.d.	0 13	0.02(7)	26	87%
Phosphorus-Ortho, Dissolved (mg/l)	0.02	30	-----	n.d.	n.d.	0.03	-----	-----	-----
Sulfate (mg/l)	1	30	131	130	74	193	250(1,3)	0	0%
Suspended Solids, Total (mg/l)	4	30	-----	9	n.d.	60	-----	-----	-----
Microcystin, Total (ug/l)	0.2	17	-----	n.d.	n.d.	0.5	-----	-----	-----

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for Class 1 lakes.
- (2) Applies to hypolimnion of Class 1 lakes during periods of thermal stratification.
- (3) Daily maximum criterion (monitoring results directly comparable to criterion).
- (4) Daily minimum criterion (monitoring results directly comparable to criterion).
- (5) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (6) 30-day average criterion (monitoring results not directly comparable to criterion).
- (7) Nutrient guideline for lake or reservoir improvement or management.

(E) The top of the hypolimnion is generally defined as the depth where a temperature drop of at least 0.5 C last occurs over a 1-meter depth increment.

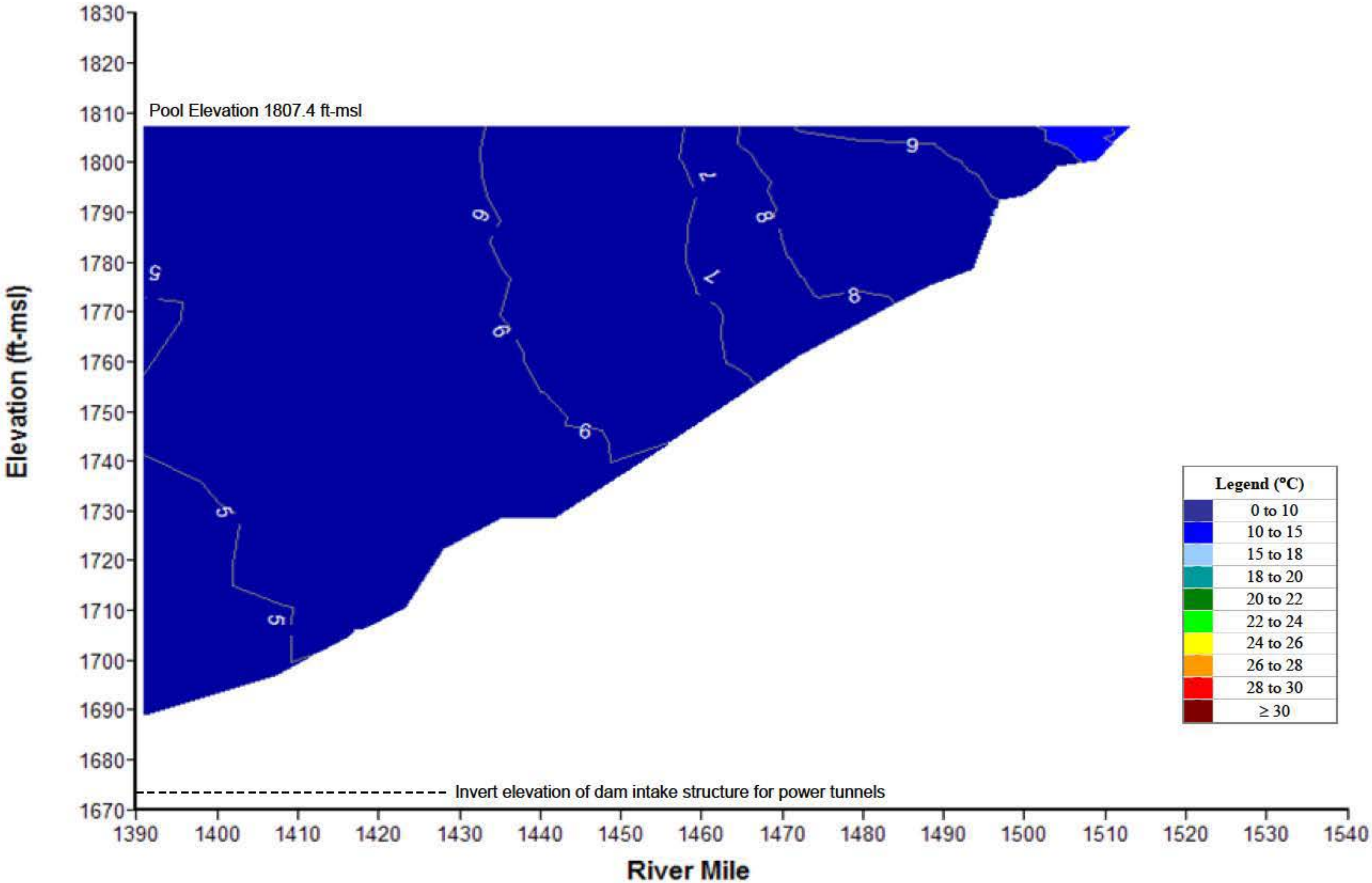


Plate 66. Longitudinal water temperature (°C) contour plot of Garrison Reservoir based on depth-profile water temperatures measured at sites GARLK1390A, GARLK1412DW, GARLK1445DW, GARLK1481DW, and GARNFMORRR1 on May 6, 2008.

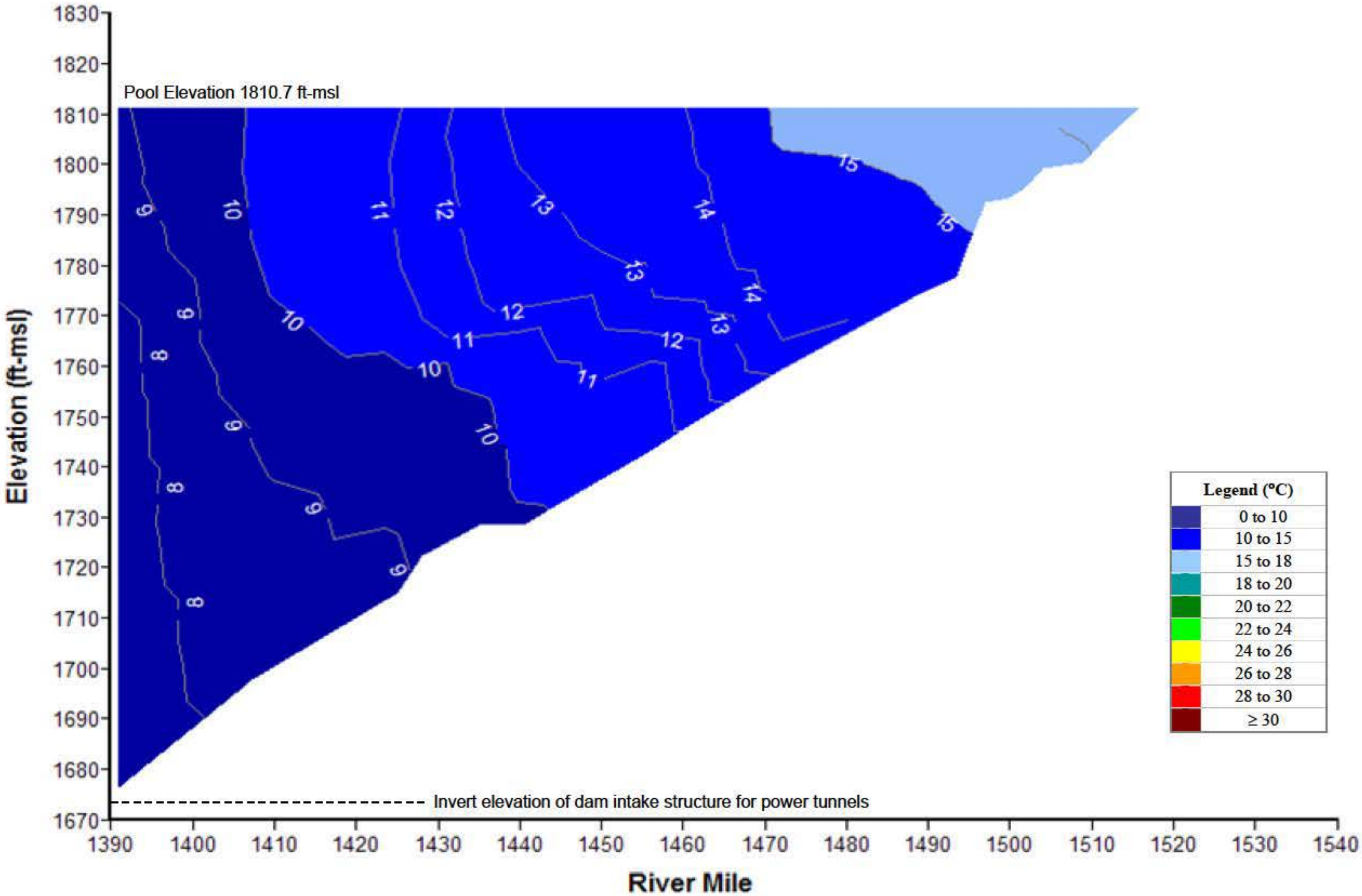


Plate 67. Longitudinal water temperature (°C) contour plot of Garrison Reservoir based on depth-profile water temperatures measured at sites GARLK1390A, GARLK1412DW, GARLK1445DW, GARLK1481DW, and GARNFMORRR1 on June 3, 2008.

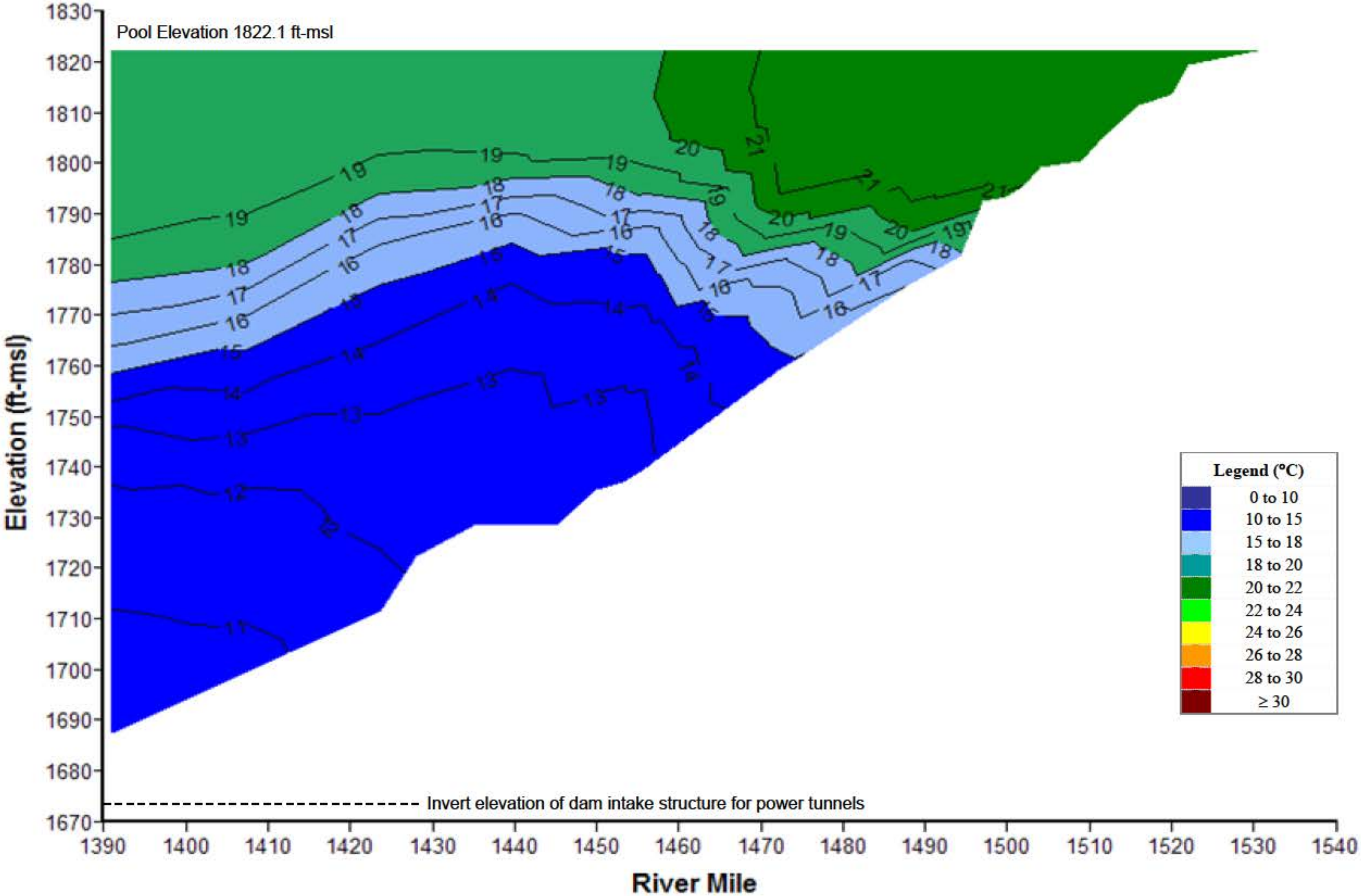


Plate 68. Longitudinal water temperature (°C) contour plot of Garrison Reservoir based on depth-profile water temperatures measured at sites GARLK1390A, GARLK1412DW, GARLK1445DW, GARLK1481DW, and GARNFMORRR1 on July 8, 2008.

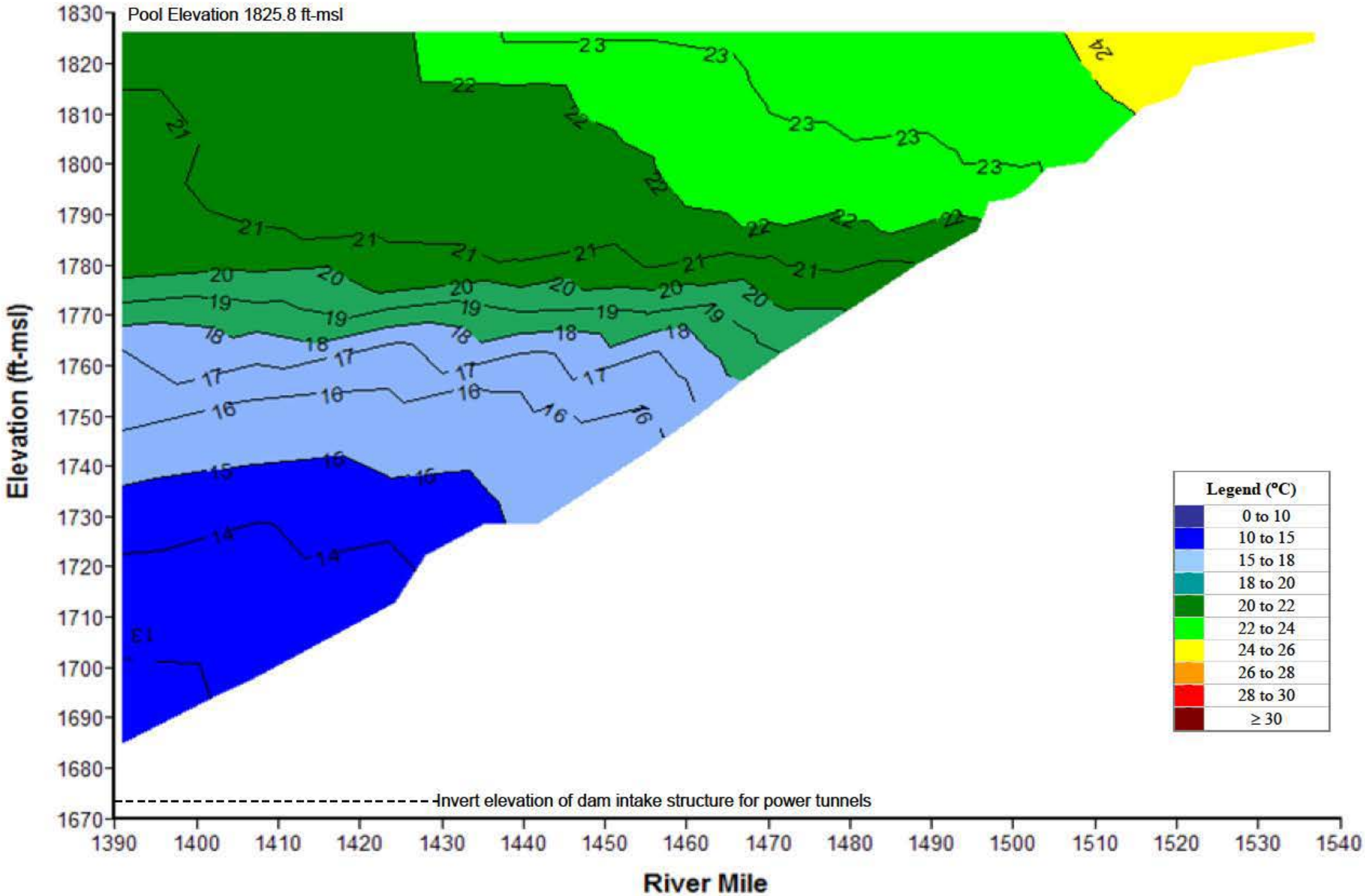


Plate 69. Longitudinal water temperature (°C) contour plot of Garrison Reservoir based on depth-profile water temperatures measured at sites GARLK1390A, GARLK1412DW, GARLK1445DW, GARLK1481DW, and GARNFMORRR1 on August 5, 2008.

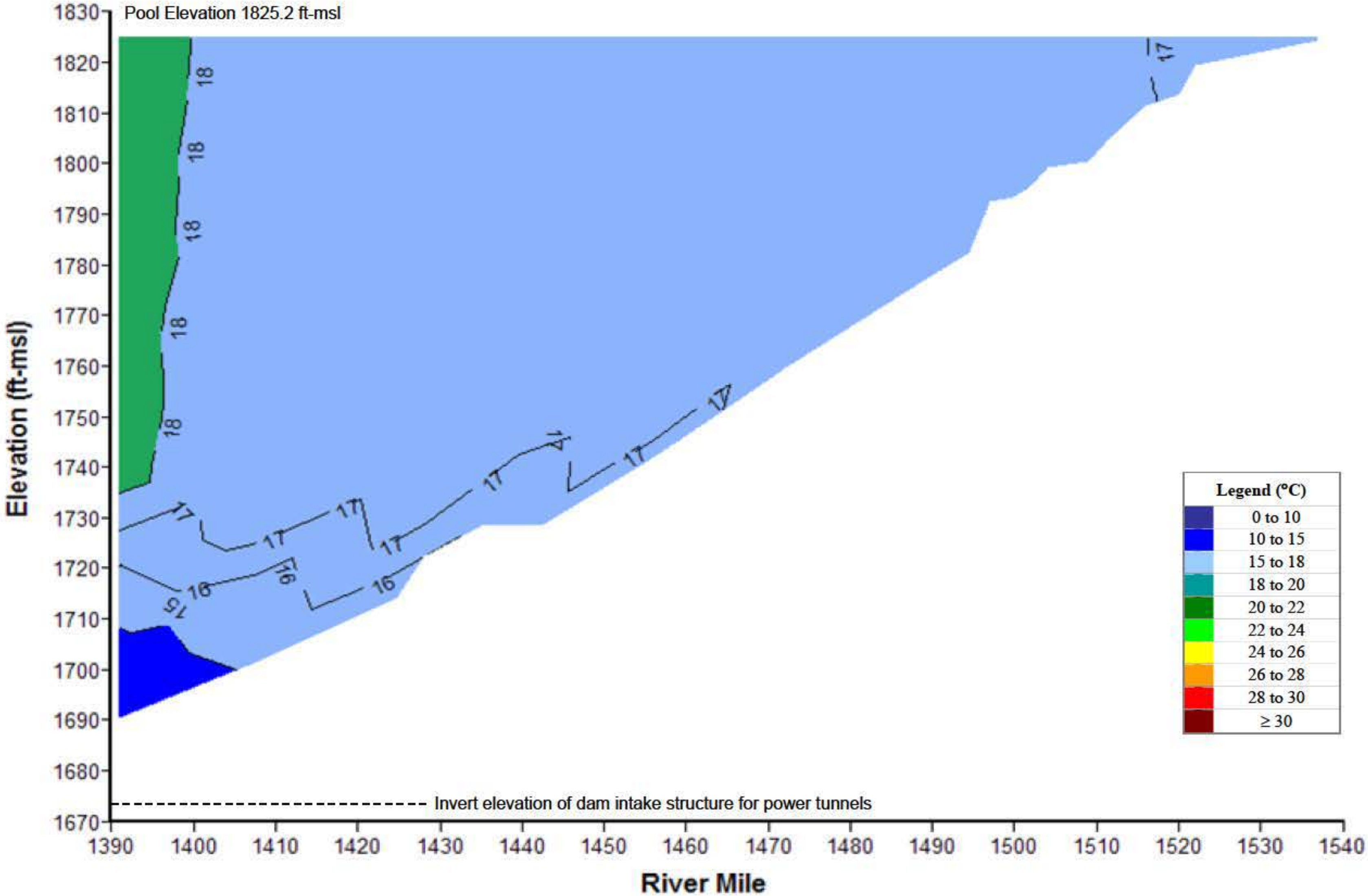


Plate 70. Longitudinal water temperature (°C) contour plot of Garrison Reservoir based on depth-profile water temperatures measured at sites GARLK1390A, GARLK1412DW, GARLK1445DW, GARLK1481DW, and GARNFMORRR1 on September 9, 2008.

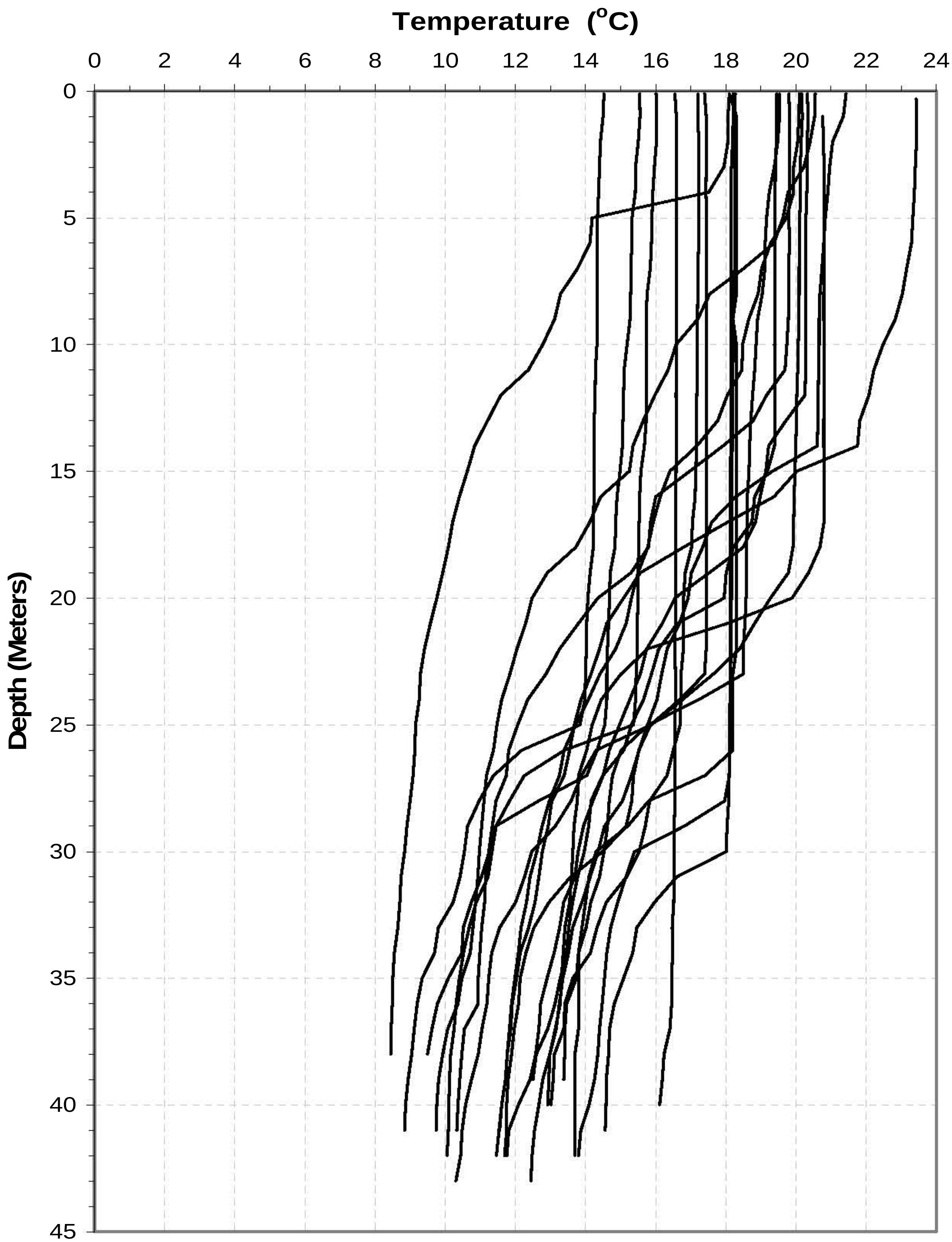


Plate 71. Temperature depth profiles for Garrison Reservoir generated from data collected at the near-dam, deepwater ambient monitoring site (i.e., GARLK1390A) during the summer months over the 5-year period of 2004 to 2008.

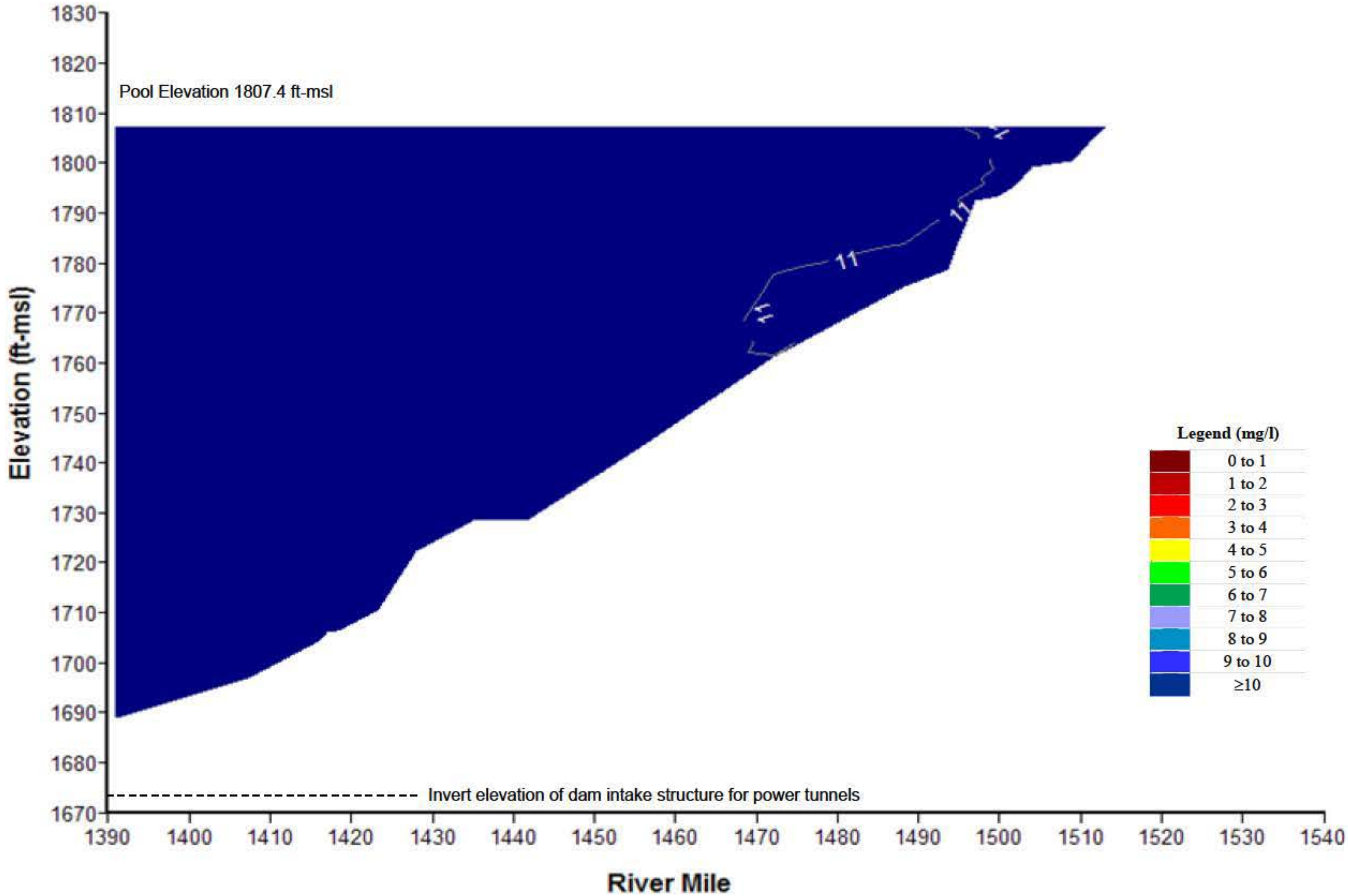


Plate 72. Longitudinal dissolved oxygen (mg/l) contour plot of Garrison Reservoir based on depth-profile dissolved oxygen concentrations measured at sites GARLK1390A, GARLK1412DW, GARLK1445DW, GARLK1481DW, and GARNFMORRR1 on May 6, 2008.

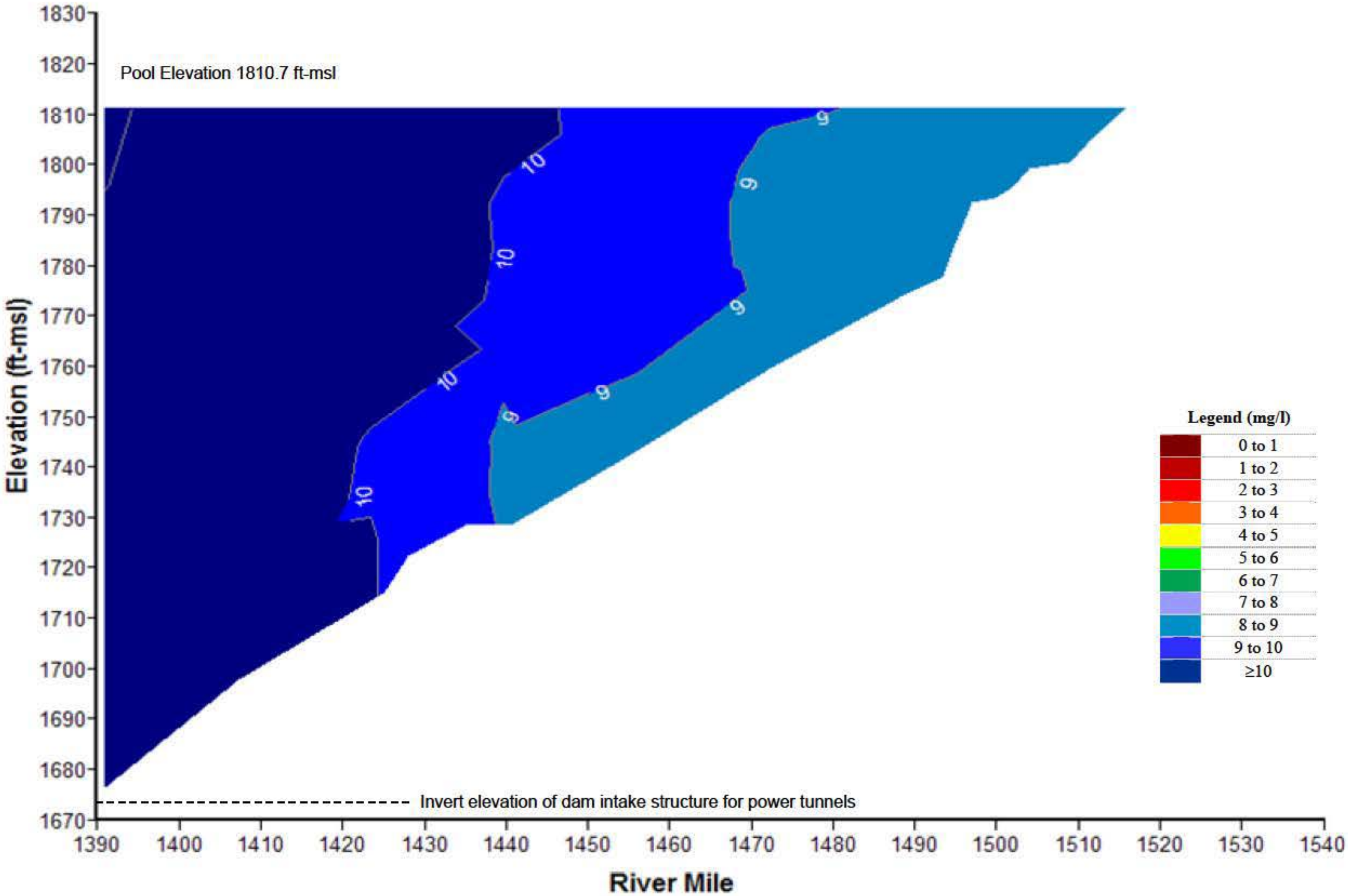


Plate 73. Longitudinal dissolved oxygen (mg/l) contour plot of Garrison Reservoir based on depth-profile dissolved oxygen concentrations s measured at sites GARLK1390A, GARLK1412DW, GARLK1445DW, GARLK1481DW, and GARNFMORRR1 on June 3, 2008.

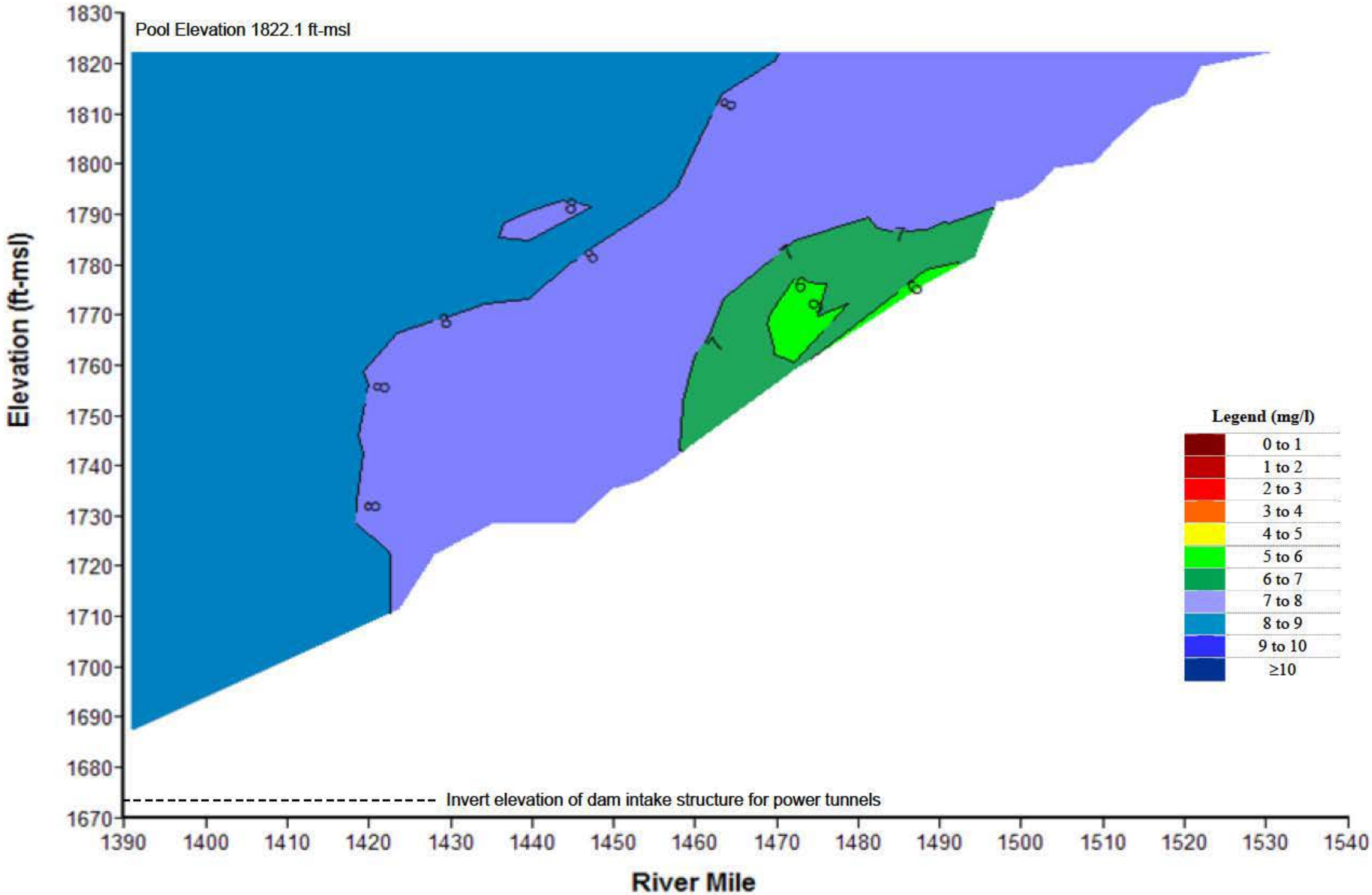


Plate 74. Longitudinal dissolved oxygen (mg/l) contour plot of Garrison Reservoir based on depth-profile dissolved oxygen concentrations measured at sites GARLK1390A, GARLK1412DW, GARLK1445DW, GARLK1481DW, and GARNFMORRR1 on July 8, 2008.

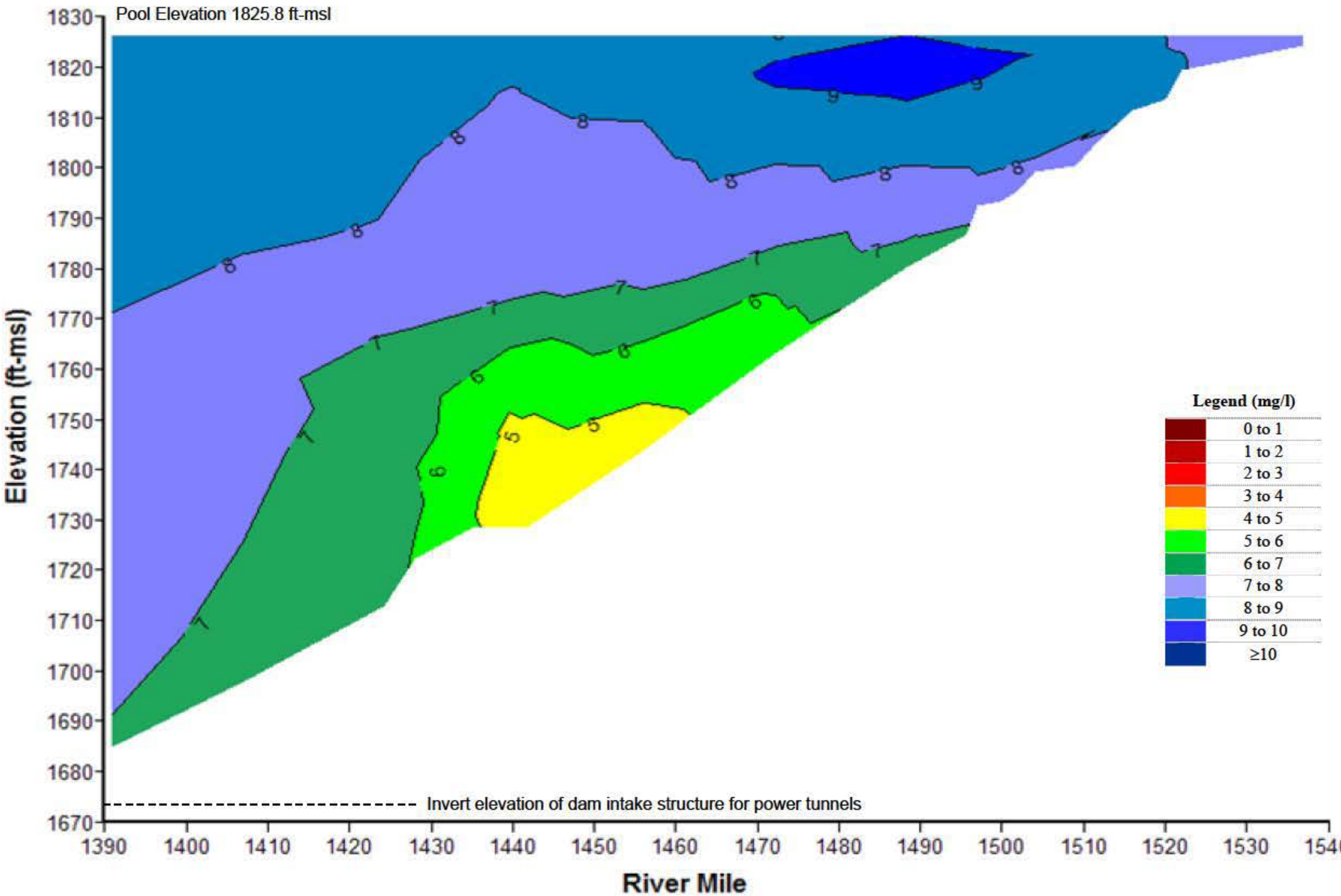


Plate 75. Longitudinal dissolved oxygen (mg/l) contour plot of Garrison Reservoir based on depth-profile dissolved oxygen concentrations measured at sites GARLK1390A, GARLK1412DW, GARLK1445DW, GARLK1481DW, and GARNFMORRR1 on August 5, 2008.

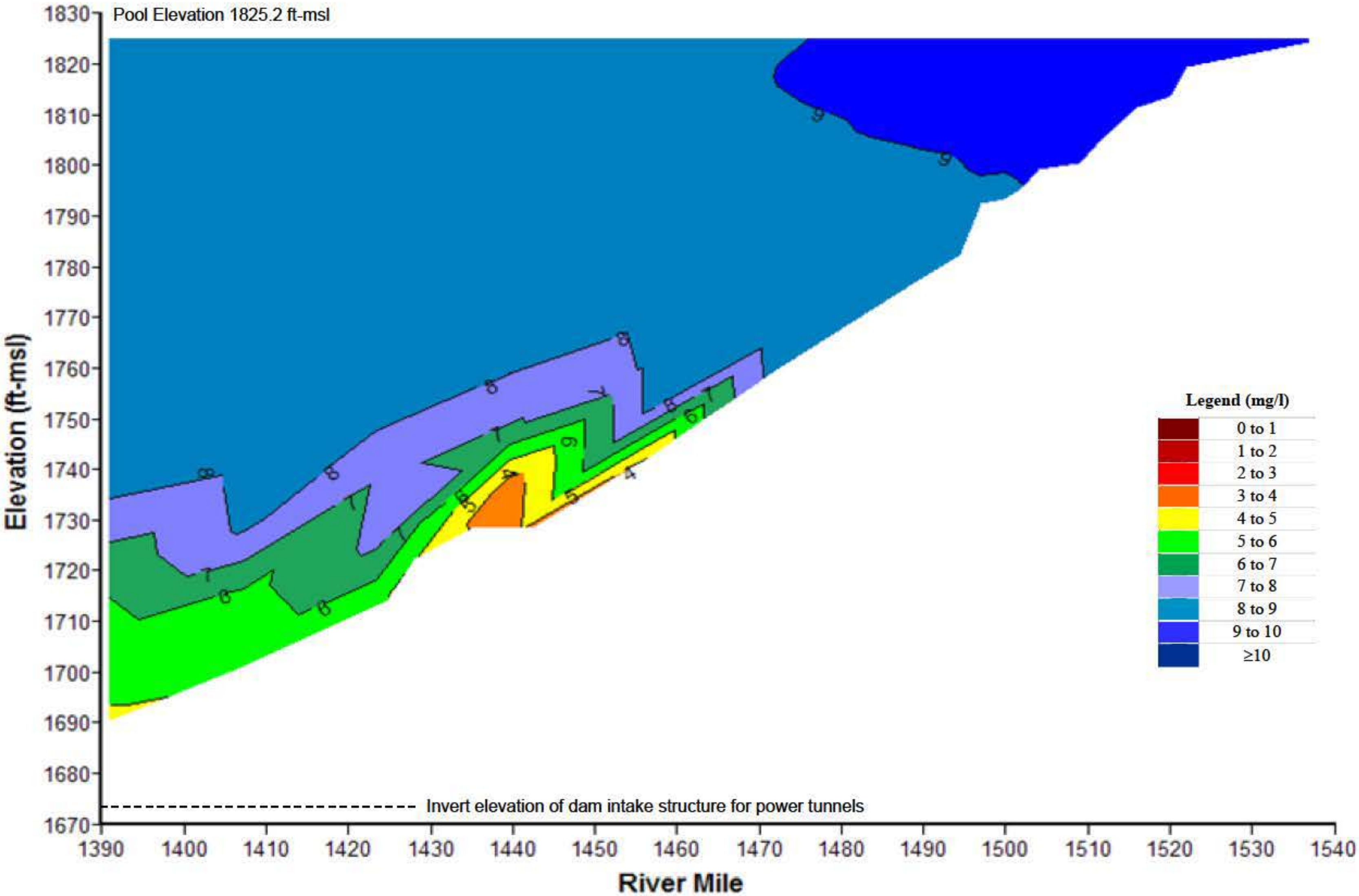


Plate 76. Longitudinal dissolved oxygen (mg/l) contour plot of Garrison Reservoir based on depth-profile dissolved oxygen concentrations measured at sites GARLK1390A, GARLK1412DW, GARLK1445DW, GARLK1481DW, and GARNFMORRR1 on September 9, 2008.

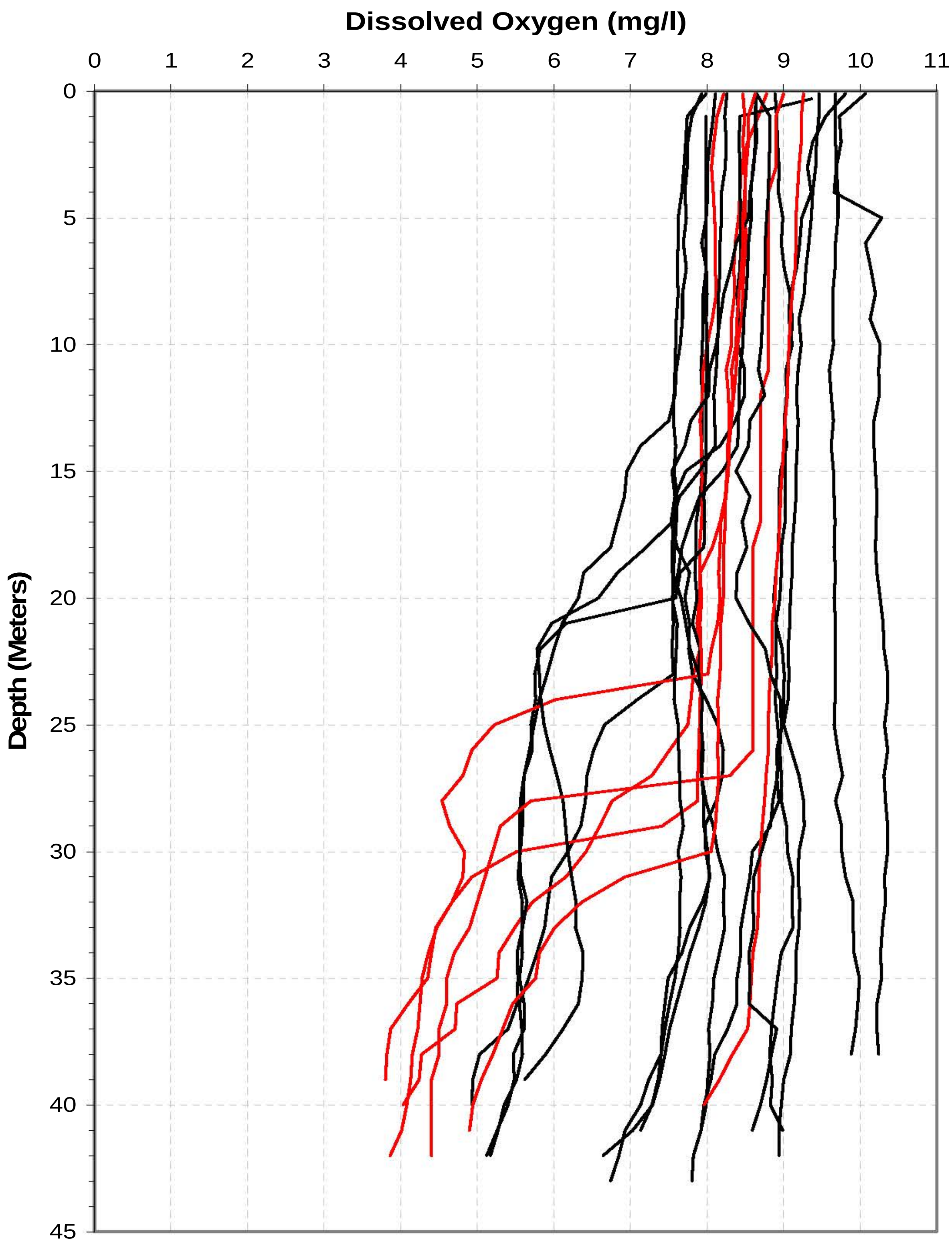


Plate 77. Dissolved oxygen depth profiles for Garrison Reservoir generated from data collected at the near-dam, deepwater ambient monitoring site (i.e., GARLK1390A) during the summer over the 5-year period of 2004 through 2008.
(Note: Red profile plots were measured in the month of September.)

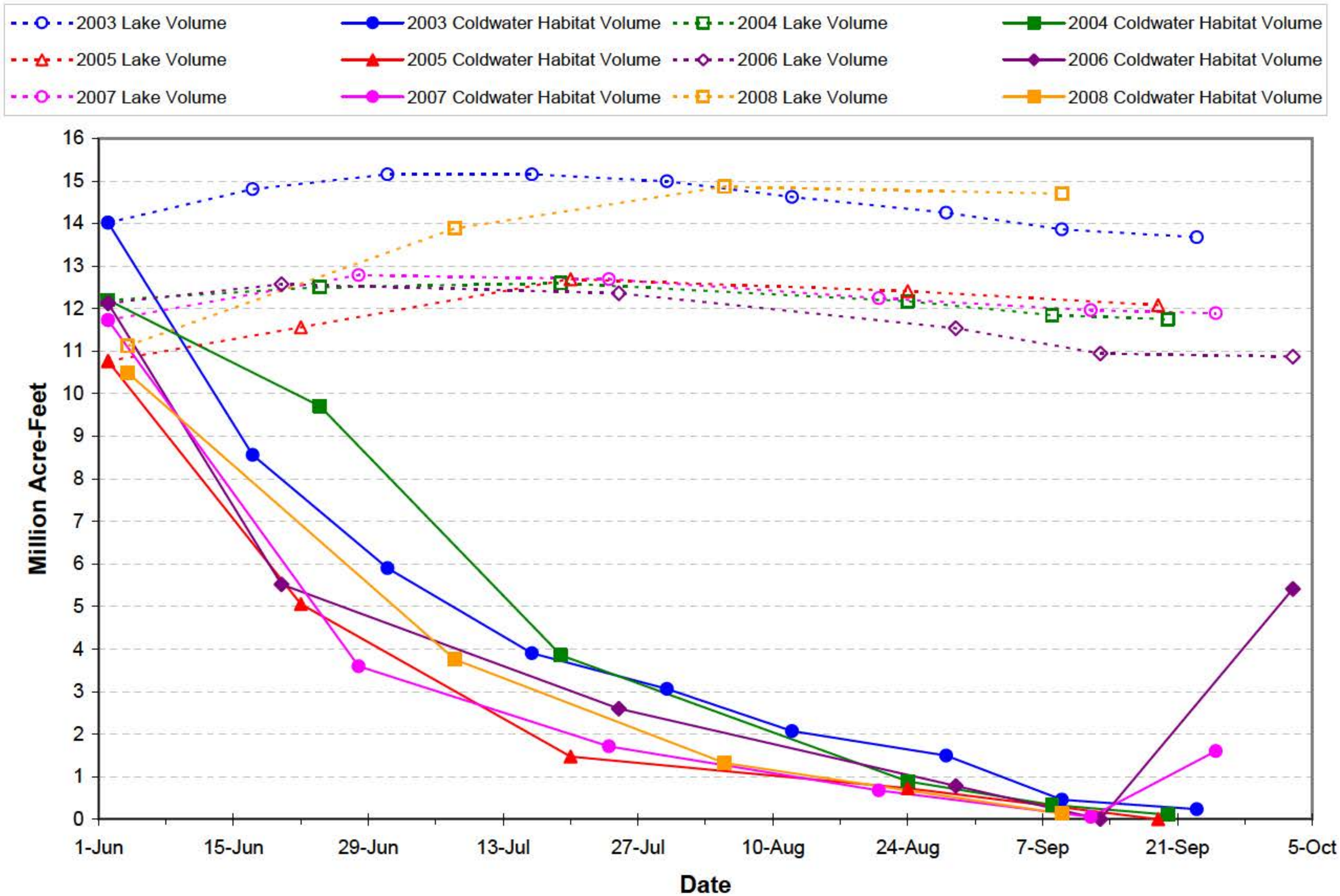


Plate 78. Estimated volume of coldwater fishery habitat in Garrison Reservoir during 2003, 2004, 2005, 2006, 2007, and 2008.

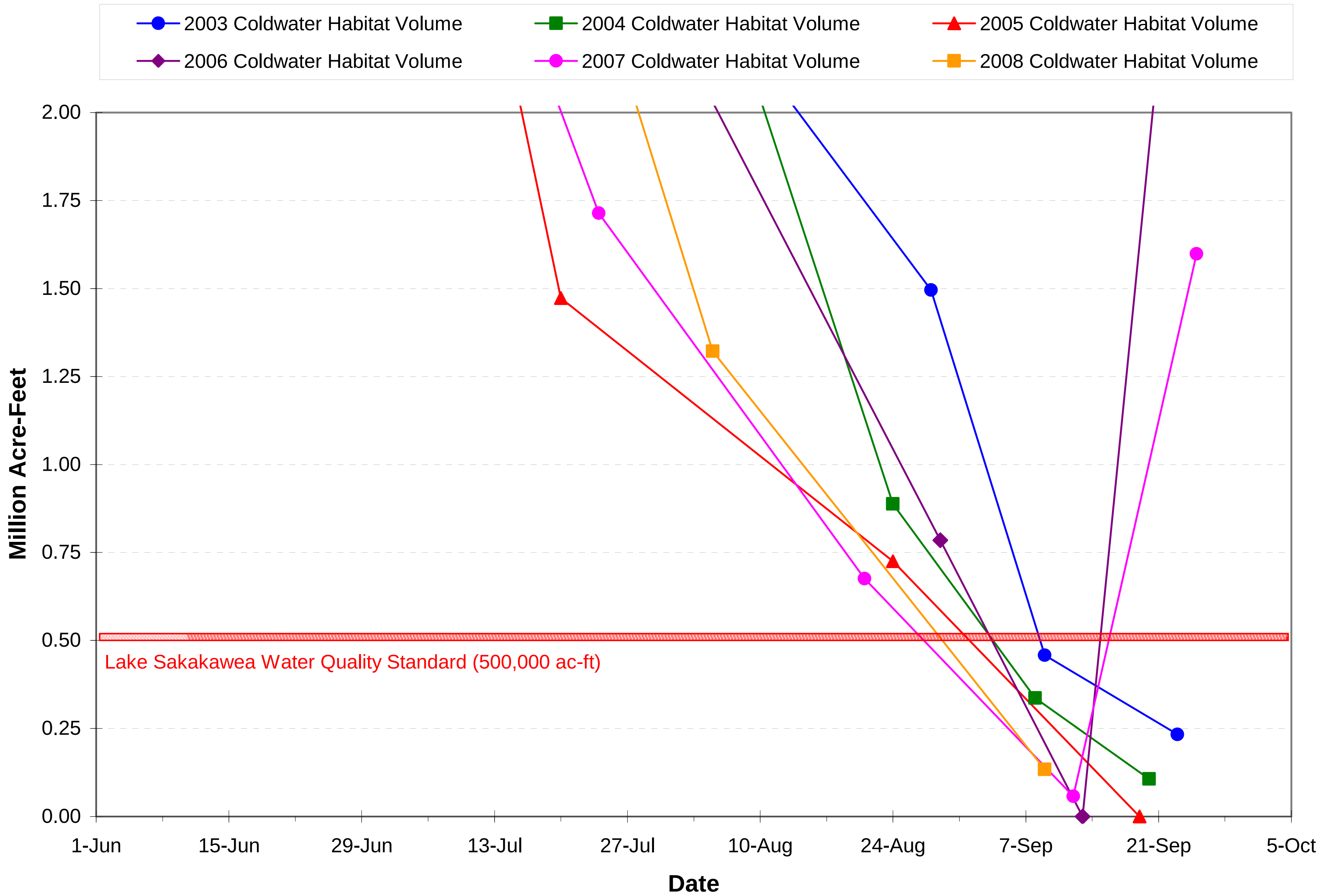


Plate 79. Estimated volume of coldwater fishery habitat in Garrison Reservoir during 2003, 2004, 2005, 2006, 2007, and 2008. Y-axis scaled to better discern estimated volumes near 500,000 ac-ft water quality standard defined by North Dakota for Lake Sakakawea.

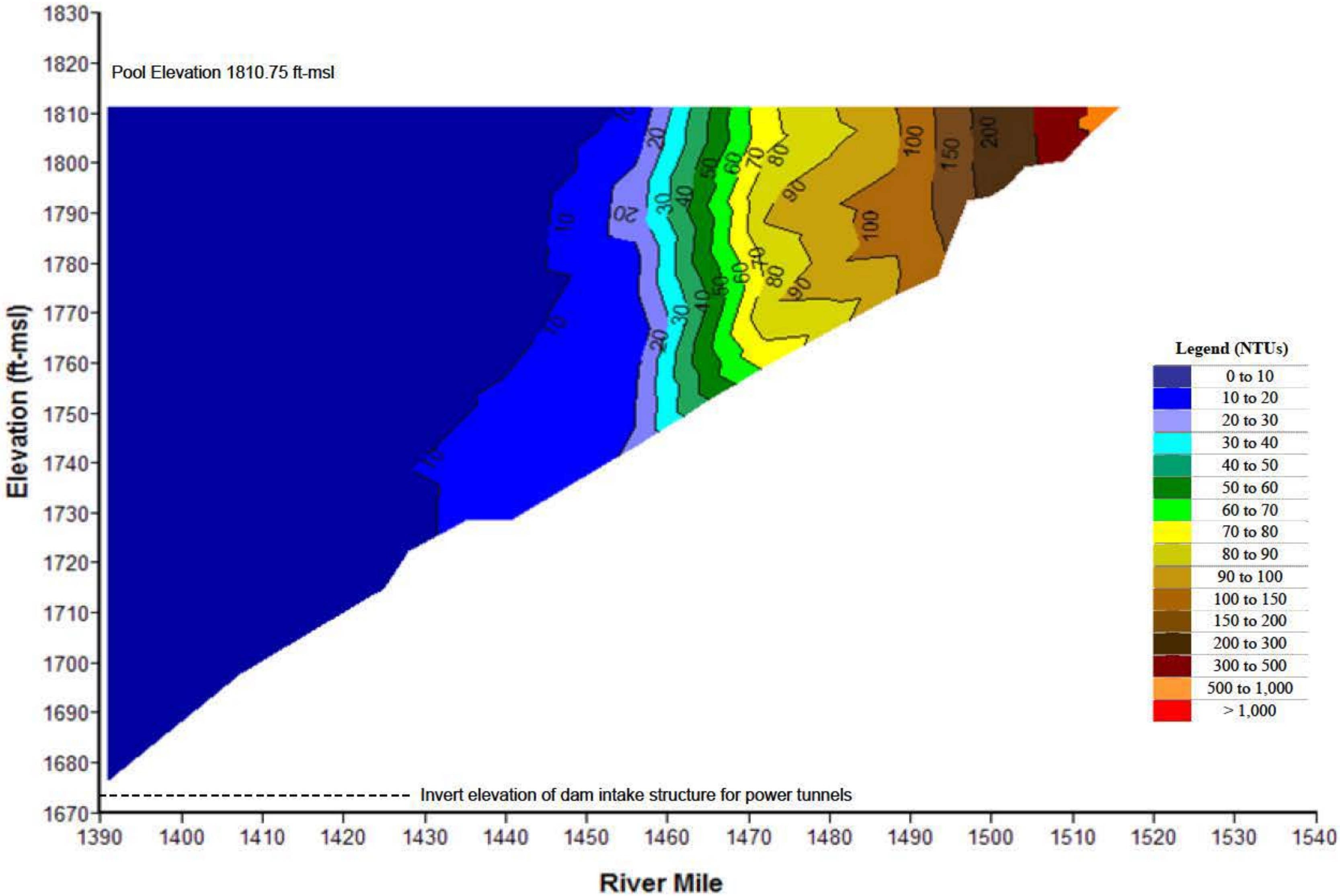


Plate 80. Longitudinal turbidity (NTU) contour plot of Garrison Reservoir based on depth-profile turbidity levels monitored at sites GARLK1390A, GARLK1412DW, GARLK1445DW, GARLK1481DW, and GARNFMORRR1 on June 6, 2008.

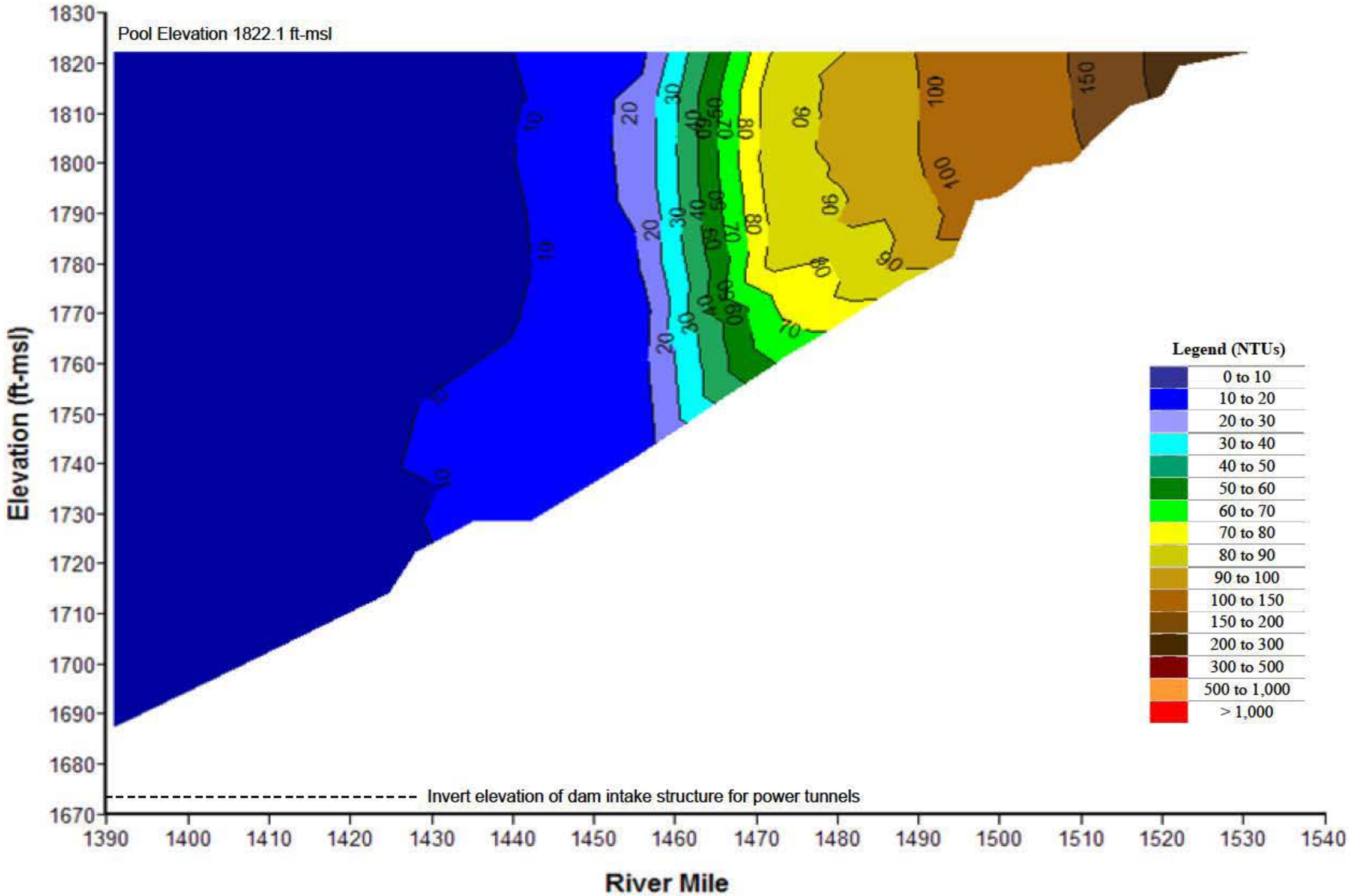


Plate 81. Longitudinal turbidity (NTU) contour plot of Garrison Reservoir based on depth-profile turbidity levels monitored at sites GARLK1390A, GARLK1412DW, GARLK1445DW, GARLK1481DW, and GARNFMORRR1 on July 8, 2008.

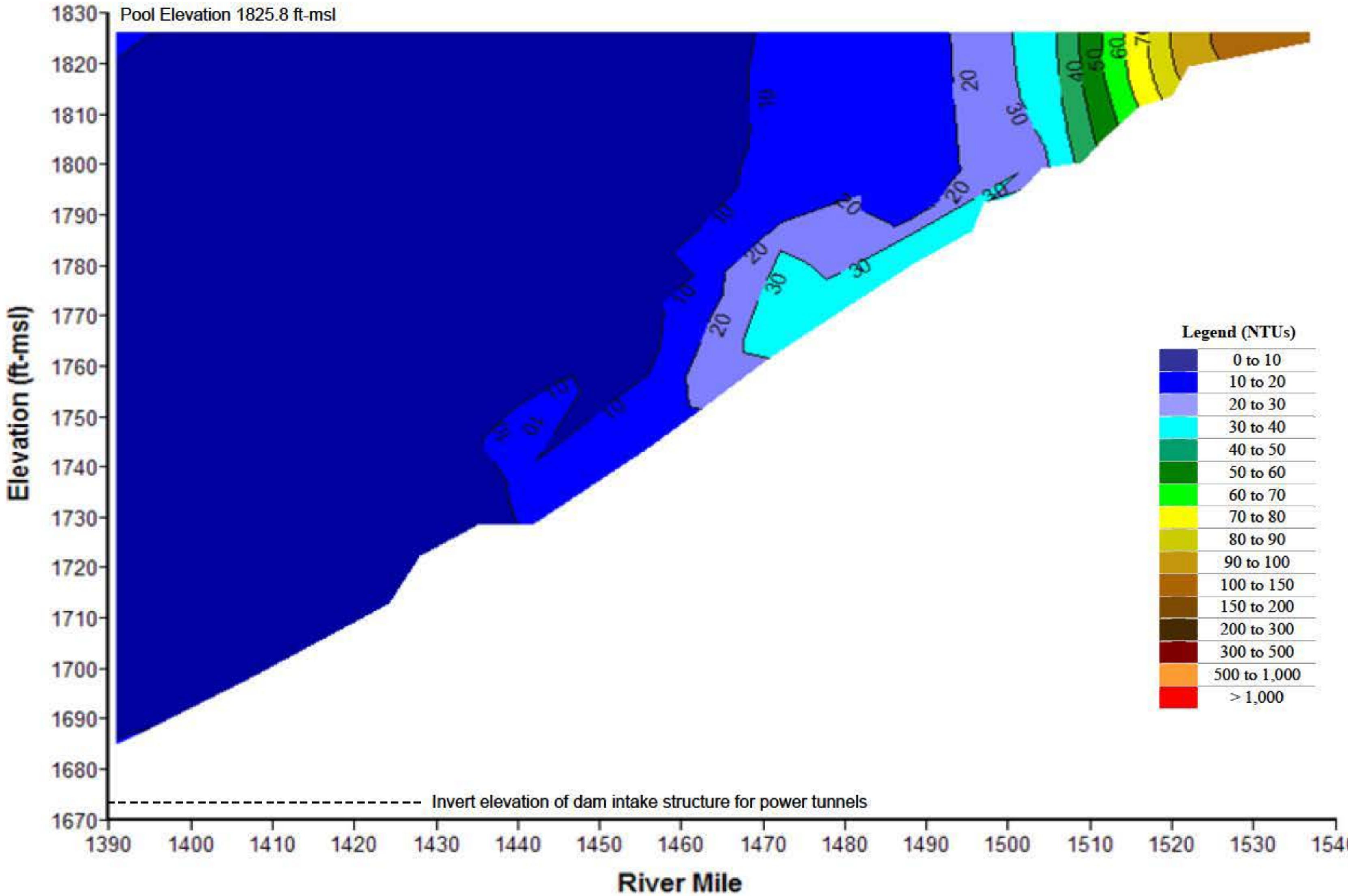


Plate 82. Longitudinal turbidity (NTU) contour plot of Garrison Reservoir based on depth-profile turbidity levels monitored at sites GARLK1390A, GARLK1412DW, GARLK1445DW, GARLK1481DW, and GARNFMORRR1 on August 5, 2008.

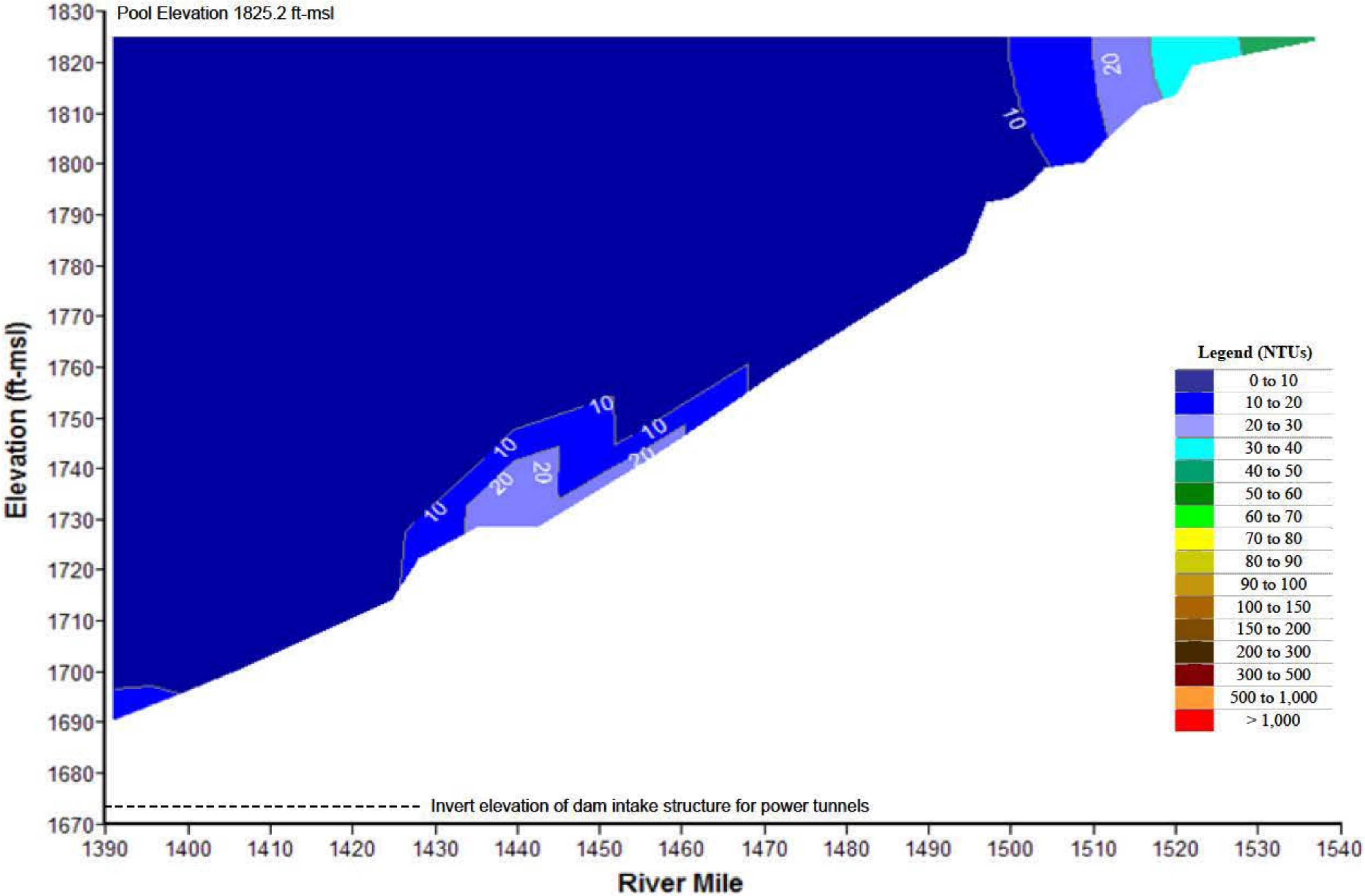


Plate 83. Longitudinal turbidity (NTU) contour plot of Garrison Reservoir based on depth-profile turbidity levels monitored at sites GARLK1390A, GARLK1412DW, GARLK1445DW, GARLK1481DW, and GARNFMORRR1 on September 9, 2008.

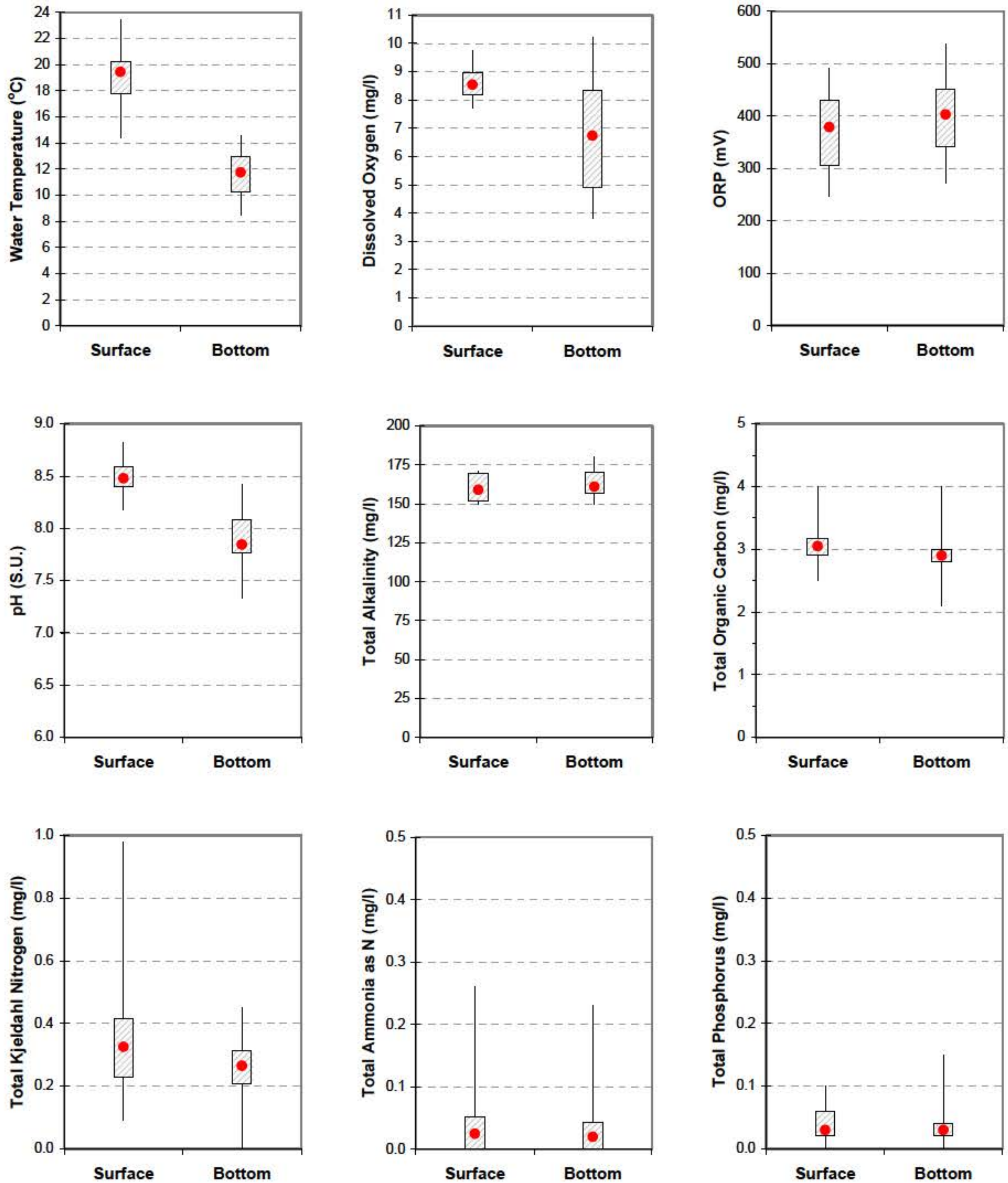


Plate 84. Box plots comparing paired surface and bottom water temperature, dissolved oxygen, oxidation-reduction potential, pH, alkalinity, total organic carbon, total Kjeldahl nitrogen, total ammonia nitrogen, and total phosphorus measurements taken in Garrison Reservoir at site GARLK1390A during the summer months of 2004 through 2008.
(Box plots display minimum, 25th percentile, 75th percentile, and maximum. Median value is indicated by the red dot.)

Plate 85. Total biovolume, number of genera present, and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected in Garrison Reservoir at site GARLK1390A during the 5-year period 2004 through 2008.

Date	Total Sample Biovolume (um³)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta		Shannon-Weaver Genera Diversity
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	
May 2004	18,358,561	3	0.58	0	-----	0	-----	1	0.03	1	0.02	1	0.37	0	-----	1.15
Jun 2004	1,982,256	2	0.53	0	-----	0	-----	1	0.35	2	0.12	0	-----	0	-----	1.15
Jul 2004	87,982,899	4	0.87	1	0.01	0	-----	1	0.11	3	<0.01	0	-----	0	-----	1.36
Aug 2004	102,328,294	5	0.83	2	0.01	0	-----	2	0.16	2	<0.01	0	-----	0	-----	1.03
Sep 2004	207,432,106	6	0.84	3	0.02	1	0.01	2	0.13	2	<0.01	1	<0.01	0	-----	1.62
May 2005	1,366,154,039	8	0.99	4	<0.01	1	<0.01	1	<0.01	0	-----	0	-----	0	-----	1.41
Jun 2005	6,163,686	1	0.88	0	-----	0	-----	0	-----	2	0.12	0	-----	0	-----	0.46
Jul 2005	56,944,302	7	0.57	2	0.19	0	-----	2	0.24	1	<0.01	0	-----	0	-----	1.82
Aug 2005	103,732,272	4	0.42	4	0.11	0	-----	1	0.29	2	<0.01	2	0.18	0	-----	1.93
Sep 2005	104,058,345	7	0.48	3	0.23	0	-----	2	0.29	2	<0.01	0	-----	0	-----	1.87
May 2006	4,548,278	2	0.36	5	0.45	0	-----	1	0.16	1	0.02	0	-----	0	-----	1.88
Jun 2006	207,770,143	3	0.99	2	<0.01	0	<0.01	1	0.01	1	<0.01	0	-----	0	-----	0.58
Jul 2006	95,265,098	4	0.95	3	0.01	0	-----	1	0.03	0	-----	0	-----	1	<0.01	0.41
Aug 2006	61,320,561	5	0.54	3	0.14	1	0.01	1	0.11	1	0.01	1	0.16	1	0.03	1.86
Oct 2006	149,224,845	6	0.82	2	0.09	0	-----	1	0.09	0	-----	0	-----	1	<0.01	1.23
May 2007	233,328,700	7	0.82	2	0.05	1	0.05	1	0.03	0	-----	1	0.05	0	-----	1.28
June 2007	460,925,551	7	0.85	2	0.08	2	0.03	1	0.04	0	-----	1	<0.01	0	-----	0.81
July 2007	61,884,196	9	0.54	9	0.21	0	-----	1	0.21	0	-----	1	0.04	0	-----	2.29
Aug 2007	95,896,430	5	0.40	8	0.05	1	0.17	1	0.06	2	<0.01	2	0.32	0	-----	1.84
Sep 2007	115,978,027	9	0.34	6	0.18	0	-----	1	0.07	3	0.01	2	0.42	0	-----	2.07
May 2008	1,157,155,594	6	1.00	1	<0.01	1	<0.01	1	<0.01	0	-----	0	-----	0	-----	0.75
Jun 2008	1,679,144,925	10	1.00	0	-----	1	<0.01	1	<0.01	1	<0.01	0	-----	0	-----	1.31
Jul 2008	348,335	5	0.99	2	<0.01	1	<0.01	1	<0.01	0	-----	0	-----	0	-----	1.26
Aug 2008	12,401,108	2	0.07	1	0.14	1	0.33	1	0.23	2	0.01	1	0.22	0	-----	1.54
Sep 2008	196,440,443	5	0.94	4	0.01	0	-----	1	0.05	1	<0.01	0	-----	0	-----	1.19
Mean*	**263,470,760**	**5.3**	**0.70**	**2.8**	**0.09**	**0.4**	**0.05**	**1.1**	**0.11**	**1.2**	**0.02**	**0.5**	**0.18**	**0.1**	**0.01**	

* Mean percent composition represents the mean when taxa of that division are present.

Plate 86. Total biovolume, number of genera present, and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected in Garrison Reservoir at site GARLK1412DW during the 5-year period 2004 through 2008.

Date	Total Sample Biovolume (um^3)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta		Shannon-Weaver Genera Diversity
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	
Jun 2004	1,223,563	0	-----	0	-----	0	-----	2	0.41	2	0.42	1	0.17	0	-----	1.54
Jul 2004	116,657,513	5	0.76	2	0.02	0	-----	2	0.23	3	<0.01	0	-----	0	-----	1.72
Aug 2004	88,140,166	7	0.85	0	-----	0	-----	2	0.15	2	<0.01	1	<0.01	0	-----	1.94
Sep 2004	135,965,507	6	0.52	1	0.23	0	-----	2	0.20	4	0.03	1	0.02	0	-----	2.01
Jul 2005	116,539,612	5	0.09	4	0.07	1	0.20	2	0.31	2	<0.01	1	0.32	0	-----	1.89
Aug 2005	252,450,665	4	0.82	2	0.09	0	-----	2	0.07	3	0.02	0	-----	0	-----	1.39
Sep 2005	76,108,173	8	0.38	5	0.11	0	-----	2	0.36	7	0.14	1	<0.01	0	-----	2.24
May 2006	217,281,884	6	1.00	1	<0.01	0	-----	1	<0.01	1	<0.01	0	-----	0	-----	1.13
Jun 2006	93,779,718	3	0.76	7	0.05	0	-----	1	0.14	0	-----	1	<0.01	1	0.05	1.13
Jul 2006	397,827,012	6	0.87	4	0.02	2	0.01	1	0.07	2	<0.01	2	0.03	0	-----	0.77
Aug 2006	123,147,584	2	0.61	6	0.07	0	-----	1	0.14	1	0.01	2	<0.01	1	0.17	1.66
Oct 2006	577,387,603	8	0.88	1	<0.01	0	-----	1	0.01	2	0.06	3	0.04	0	-----	1.22
May 2007	111,867,224	11	0.69	3	0.17	1	0.06	1	0.08	0	-----	0	-----	0	-----	1.44
June 2007	119,135,131	8	0.65	5	0.13	2	0.15	1	0.07	0	-----	0	-----	0	-----	1.64
July 2007	204,517,663	6	0.72	6	0.07	1	0.03	1	0.09	2	0.01	1	0.07	0	-----	1.67
Aug 2007	157,266,490	6	0 26	7	0.17	2	0.01	1	0.10	3	0.01	1	0.46	0	-----	1.61
Sep 2007	229,575,999	7	0.54	5	0.06	1	<0.01	2	0.03	5	0.02	1	0.35	0	-----	1.66
May 2008	757,782,264	6	1.00	1	<0.01	1	<0.01	1	<0.01	1	<0.01	1	<0.01	0	-----	0.34
Jun 2008	738,288,567	9	0.99	0	-----	2	<0.01	0	<0.01	0	<0.01	0	-----	0	-----	1.06
Jul 2008	111,538	3	0 19	6	0.16	2	0.03	1	0.56	0	-----	2	0.06	0	-----	1.43
Aug 2008	53,024,103	5	0.69	4	0.01	2	0.13	1	0.16	0	-----	3	0.01	0	-----	1.04
Sep 2008	250,365,850	6	0.93	2	0.01	0	-----	1	0.05	1	<0.01	2	0.01	0	-----	1.15
Mean*	**219,020,174**	**5.8**	**0.68**	**3.3**	**0.08**	**0.8**	**0.06**	**1.3**	**0.15**	**1.9**	**0.04**	**1.1**	**0.10**	**0.1**	**0.11**	**1.44**

* Mean percent composition represents the mean when taxa of that division are present.

Plate 87. Total biovolume, number of genera present, and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected in Garrison Reservoir at site GARLK1445DW during the 5-year period 2004 through 2008.

Date	Total Sample Biovolume (um^3)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta		Shannon-Weaver Genera Diversity
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	
Jun 2004	1,685,612	3	0.62	0	-----	0	-----	1	0.21	3	0.17	0	-----	0	-----	1.46
Jul 2004	184,759,537	7	0 97	0	-----	0	-----	2	0.03	2	<0.01	0	-----	0	-----	1.07
Aug 2004	286,075,340	5	0.88	4	0.01	1	0.01	1	0.05	8	0.03	2	0.03	0	-----	1.44
Sep 2004	155,608,125	6	0.73	7	0.22	0	-----	1	0.03	4	0.02	1	<0.01	1	<0.01	1.81
Jun 2005	117,713,953	3	0.66	3	0.21	0	-----	2	0.11	4	0.01	1	<0.01	0	-----	1.50
Jul 2005	72,156,390	5	0.46	2	<0.01	1	0.23	1	0.08	3	0.01	1	0.23	0	-----	1.65
Aug 2005	355,699,437	6	0.73	2	0.05	1	0.01	2	0.07	8	0.15	0	-----	0	-----	1.71
Sep 2005	177,778,515	1	0.08	5	0.36	0	-----	1	0.04	8	0.50	2	0.03	0	-----	1.64
May 2006	494,273,807	7	0.99	1	<0.01	0	-----	2	<0.01	1	<0.01	0	-----	0	-----	1.18
Jun 2006	49,254,498	8	0.73	5	0.08	1	0.02	1	0.17	0	-----	0	-----	0	-----	2.02
Jul 2006	271,528,998	3	0.73	5	0.01	1	<0.01	1	0.22	3	0.03	1	<0.01	0	-----	1.31
Aug 2006	252,320,396	4	0.81	4	0.05	0	-----	1	0.07	1	0.05	1	0.02	0	-----	1.40
Oct 2006	360,297,717	7	0.51	12	0.36	0	-----	1	0.04	6	0.08	1	0.01	0	-----	2.00
May 2007	4,434,931,365	12	0.98	5	0.02	0	-----	1	<0.01	0	-----	0	-----	0	-----	0.59
June 2007	160,826,868	8	0.73	9	0.19	0	-----	2	0.05	0	-----	1	0.02	0	-----	1.45
July 2007	305,880,416	7	0.80	7	0.04	1	0.04	1	0.05	3	0.05	1	0.03	0	-----	1.13
Aug 2007	215,286,031	6	0.34	8	0.16	0	-----	1	0.15	3	<0.01	1	0.33	1	0.01	1.92
Sep 2007	253,797,184	8	0.80	10	0.06	0	-----	1	0.02	4	0.01	1	0.12	0	-----	1.76
May 2008	521,560,198	13	0.90	2	<0.01	0	-----	1	0.10	0	-----	0	-----	0	-----	1.78
Jun 2008	1,111,366,450	9	1.00	4	<0.01	0	-----	1	<0.01	0	-----	0	-----	0	-----	1.31
Jul 2008	130,720	8	0.63	4	0.07	0	0.01	1	0.29	0	-----	0	-----	0	-----	1.33
Aug 2008	628,082,994	6	0 94	3	<0.01	0	-----	1	0.06	2	<0.01	0	-----	0	-----	1.30
Sep 2008	37,854,056	3	0.34	4	0.13	0	-----	1	0.21	2	0.33	0	-----	0	-----	1.68
Mean*	**454,298,635**	**6.3**	**0.71**	**4.6**	**0.10**	**0.3**	**0.05**	**1.2**	**0.09**	**2.8**	**0.09**	**0.6**	**0.07**	**0.1**	**0.01**	**1.50**

* Mean percent composition represents the mean when taxa of that division are present.

Plate 88. Total biovolume, number of genera present, and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected in Garrison Reservoir at site GARLK1481DW during the 5-year period 2004 through 2008.

Date	Total Sample Biovolume (um^3)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta		Shannon-Weaver Genera Diversity
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	
Jun 2004	641,406,981	7	0.95	1	<0.01	0	-----	2	0.04	4	<0.01	1	<0.01	1	<0.01	1.24
Jul 2004	143,415,460	10	0.65	1	<0.01	0	-----	2	0.34	4	<0.01	0	-----	1	<0.01	1.67
Aug 2004	116,129,651	6	0.94	3	0.01	0	-----	2	0.02	1	<0.01	2	0.03	0	-----	1.41
Sep 2004	212,398,576	8	0.77	11	0.10	0	-----	2	0.09	4	0.03	2	<0.01	1	0.01	2.03
Jun 2005	162,736,064	4	0.48	6	0.24	0	-----	2	0.23	3	0.01	1	0.03	1	<0.01	2.06
Jul 2005	45,637,096	3	0 95	3	0.04	0	-----	1	0.01	1	<0.01	0	-----	0	-----	1.26
Aug 2005	123,071,200	4	0.52	6	0.13	0	-----	2	0.16	5	0.05	2	0.14	0	-----	1.80
Sep 2005	136,453,161	10	0.30	10	0.47	0	-----	2	0.10	8	0.07	1	0.04	1	0.02	2.07
May 2006	350,014,023	10	0.90	9	0.03	2	0.01	1	<0.01	1	<0.01	2	0.04	3	0.01	2.06
Jun 2006	271,464,027	8	0.96	4	0.02	0	-----	1	<0.01	1	0.01	0	-----	1	<0.01	0.99
Jul 2006	109,852,109	7	0.29	7	0.11	1	0.02	1	0.49	3	0.05	1	0.03	0	-----	1.96
Aug 2006	226,689,591	8	0.36	13	0.25	1	0.01	1	0.06	3	0.26	2	0.05	3	0.02	2.69
Oct 2006	1,395,049,142	10	0.78	17	0.05	2	0.03	2	0.01	6	0.12	2	0.01	2	0.01	2.16
May 2007	2,999,852,220	11	0.89	7	0.11	0	-----	1	0.01	0	-----	0	-----	0	-----	0.93
June 2007	513,050,143	10	0.87	7	0.10	0	-----	1	0.02	1	<0.01	0	-----	0	-----	1.29
July 2007	254,413,324	9	0 13	6	0.11	1	<0.01	1	0.13	4	0.62	1	0.02	0	-----	2.01
Aug 2007	222,884,487	8	0.33	8	0.16	1	<0.01	1	0.15	5	0.03	1	0.32	2	0.01	2.05
Sep 2007	918,618,938	10	0.82	12	0.04	1	0.01	2	0.01	4	0.06	2	0.04	2	0.02	2.02
May 2008	1,419,301,364	12	0.99	2	<0.01	1	0.01	1	<0.01	1	<0.01	0	-----	1	<0.01	1.62
Jun 2008	357,464,958	10	1.00	1	<0.01	0	-----	1	<0.01	0	-----	0	-----	0	<0.01	1.45
Jul 2008	172,911	7	0 90	3	<0.01	0	-----	1	0.08	0	-----	1	<0.01	1	0.01	1.60
Aug 2008	856,371,701	7	0.87	7	0.08	2	<0.01	1	0.03	4	<0.01	2	0.01	2	<0.01	1.57
Sep 2008	1,278,523,241	5	0.95	6	0.02	1	<0.01	1	0.02	5	0.01	1	<0.01	1	<0.01	0.78
Mean*	**554,563,929**	**8.0**	**0.72**	**6.5**	**0.09**	**0.6**	**0.01**	**1.4**	**0.09**	**3.0**	**0.07**	**1.0**	**0.05**	**1.0**	**0.01**	**1.68**

* Mean percent composition represents the mean when taxa of that division are present.

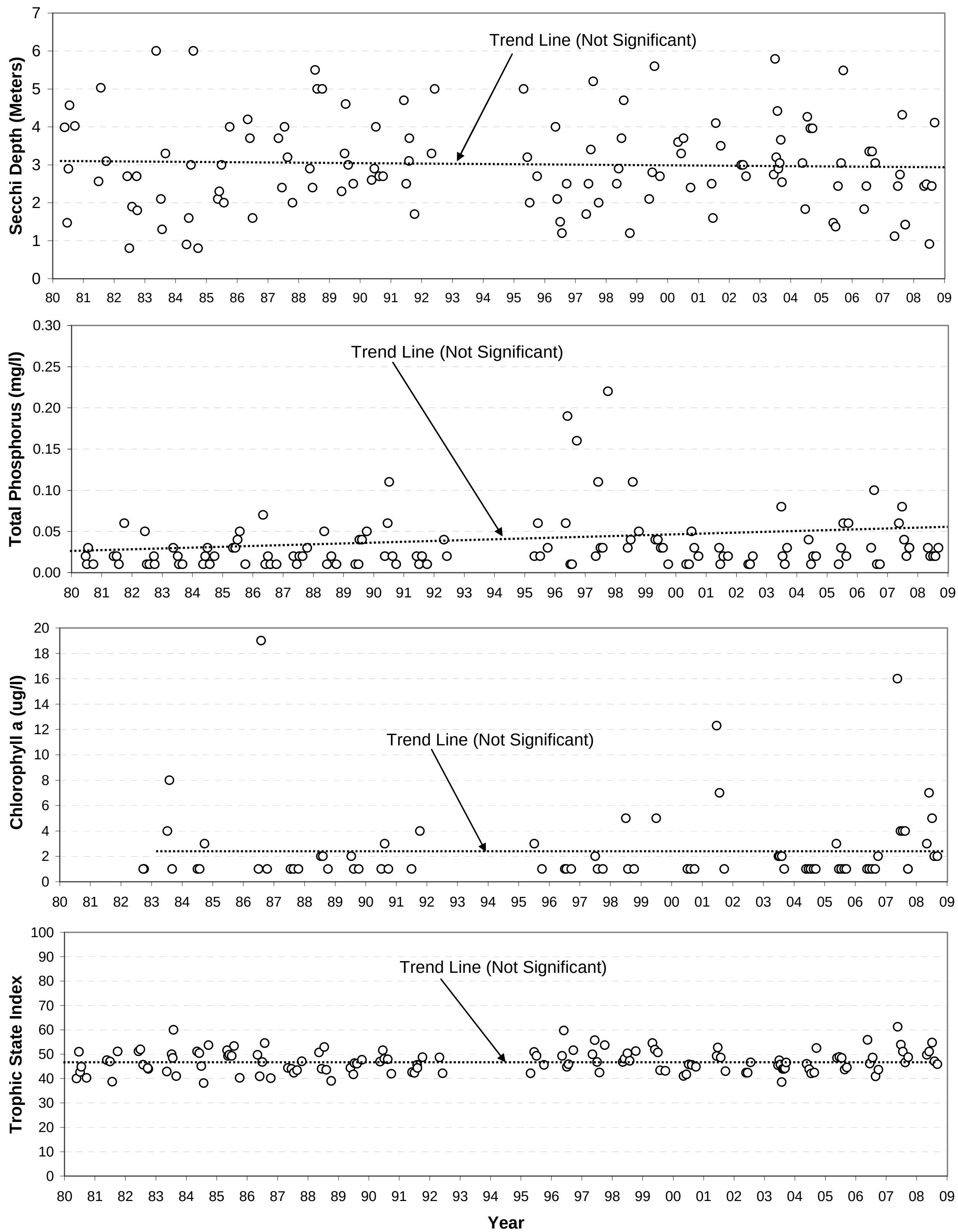


Plate 89. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and Trophic State Index (TSI) monitored in Garrison Reservoir at the near-dam, ambient site (i.e., site GARLK1390A) over the 29-year period of 1980 through 2008.

Plate 90. Summary of monthly (April through September) water quality conditions monitored in the Missouri River near Williston, North Dakota (Site GARNFMORRR1) during the 5-year period 2004 through 2008.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit[A]	No. of Obs.	Mean[B]	Median	Min.	Max.	State WQS Criteria[C]	No. of WQS Exceedences	Percent WQS Exceedence
Stream Flow (cfs)	1	27	18,350	14,016	7,648	52,320	-----	-----	-----
Water Temperature (C)	0.1	27	19.6	20.1	12.5	30.9	29.4[1,2]	1	4%
Dissolved Oxygen (mg/l)	0.1	27	8.4	8.2	6.8	10.2	5[1,3]	0	0%
Dissolved Oxygen (% Sat.)	0.1	27	94.6	94.2	78.1	105.0	-----	-----	-----
pH (S.U.)	0.1	27	8.4	8.4	7.9	8.7	7.0[1,3], 9.0[1,2]	0	0%
Specific Conductance (umho/cm)	1	27	530	564	292	725	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	27	342	334	236	486	-----	-----	-----
Turbidity (NTU)	1	27	306	119	6	1,234	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	13	32	18	4	120	-----	-----	-----
Alkalinity, Total (mg/l)	7	27	142	150	89	188	-----	-----	-----
Ammonia, Total (mg/l)	0.02	27	------	0.03	n.d.	0.50	3.88 [1,2,4], 0.85 [1,4,5]	0	0%
Carbon, Total Organic (mg/l)	0.05	26	3.0	2.9	1.5	5.5	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	18	18	11	3	93	-----	-----	-----
Chloride, Dissolved (mg/l)	1	17	9	9	4	17	100[1,2]	0	0%
Dissolved Solids, Total (mg/l)	5	26	388	382	214	633	-----	-----	-----
Hardness, Total (mg/l)	0.4	3	206	205	181	231	-----	-----	-----
Iron, Total (ug/l)	40	17	7,998	6,137	1,979	32,066	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	27	0.7	0.6	0.1	1.8	-----	-----	-----
Manganese, Total (ug/l)	2	17	179	132	54	629	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	27	-----	n.d.	n.d.	0.30	1.0[1,2]	0	0%
Phosphorus, Dissolved (mg/l)	0.02	26	-----	0.02	n.d.	0.18	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	27	0.32	0.20	0.04	1.10	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	27	-----	n.d.	n.d.	0.03	-----	-----	-----
Sulfate (mg/l)	1	27	140	156	64	194	250[1,2]	0	0%
Suspended Solids, Total (mg/l)	4	27	361	166	37	2,156	-----	-----	-----
Aluminum, Dissolved (ug/l)	25	2	-----	25	n.d.	50	-----	-----	-----
Aluminum, Total (ug/l)	25	2	5,496	5,496	3,001	7,990	750[6]	2	100%
Antimony, Total (ug/l)	0.5	2	-----	n.d.	n.d.	n.d.	5.6[8]	0	0%
Arsenic, Total (ug/l)	1	2	5	5	4	6	340[6], 150[7], 10[8]	0	0%
Barium, Total (ug/l)	5	2	66	66	50	81	1,000[8]	0	0%
Beryllium, Total (ug/l)	2	2	-----	n.d.	n.d.	n.d.	4[8]	0	0%
Cadmium, Total (ug/l)	0.2	2	-----	n.d.	n.d.	n.d.	4.4[6], 0.5[7], 5[8]	0	0%
Chromium, Total (ug/l)	10	2	-----	n.d.	n.d.	n.d.	3,246[6], 155[7], 100[8]	0	0%
Copper, Total (ug/l)	2	2	-----	n.d.	n.d.	n.d.	27.5[6], 17.2[7], 1,000[8]	0	0%
Lead, Total (ug/l)	0.5	2	3.5	3.5	3.0	4.0	204[6], 7.9[7], 15[8]	0	0%
Mercury, Total (ug/l)	0.02	2	-----	n.d.	n.d.	n.d.	1.7[6], 0.012[7], 0.05[8]	0, b.d., 0	0%, b.d., 0%
Nickel, Total (ug/l)	10	2	-----	n.d.	n.d.	10	861[6], 96[7], 100[8]	0	0%
Selenium, Total (ug/l)	1	2	-----	n.d.	n.d.	n.d.	20[6], 5[7], 50[8]	0	0%
Silver, Total (ug/l)	1	2	-----	n.d.	n.d.	n.d.	13.7[6]	0	0%
Thallium, Total (ug/l)	0.5	2	-----	n.d.	n.d.	n.d.	0.24[7]	b.d.	b.d.
Zinc, Total (ug/l)	10	2	47	47	13	80	220[6,7], 7,400[8]	0	0%
Pesticide Scan (ug/l)[D]	0.05	2	-----	n.d.	n.d.	n.d.	-----	-----	-----

n.d. = Not detected. b.d. = Criterion below detection limit.

(A) Detection limits given for the parameters Stream Flow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for Class 1 streams.
- (2) Daily maximum criterion (monitoring results directly comparable to criterion).
- (3) Daily minimum criterion (monitoring results directly comparable to criterion).
- (4) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (5) 30-day average criterion (monitoring results not directly comparable to criterion).
- (6) Acute criterion for aquatic life.
- (7) Chronic criterion for aquatic life.
- (8) Human health criterion for surface waters.

Note: Some of North Dakota's criteria for metals (i e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

(D) The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, cycloate, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, isopropalin, metolachlor, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, phorate, profluralin, prometon, propachlor, propazine, simazine, terbufos, triallate, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

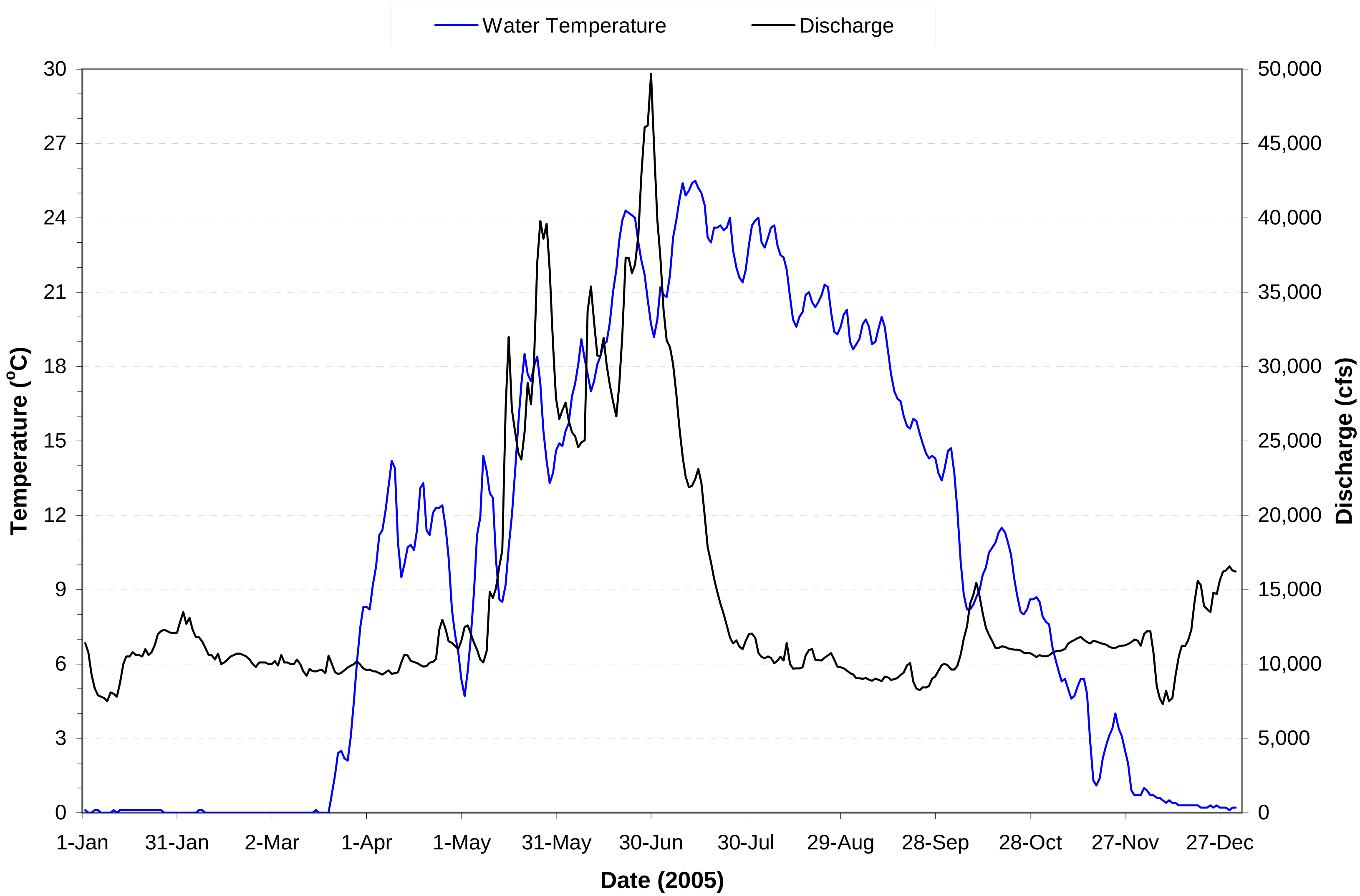


Plate 91. Mean daily water temperature and discharge of the Missouri River near Williston, North Dakota (i.e., site GARNFMORRR1) for 2005. Mean temperatures based on hourly measurements recorded on the Missouri River near Williston, North Dakota (USGS gaging station 06330000). Mean daily discharge estimated by adding mean daily discharge recorded for the Missouri River near Culbertson, Montana (USGS gaging station 06185500) and the mean daily discharge recorded for the Yellowstone River near Sidney, Montana (USGS gaging station 06329500).

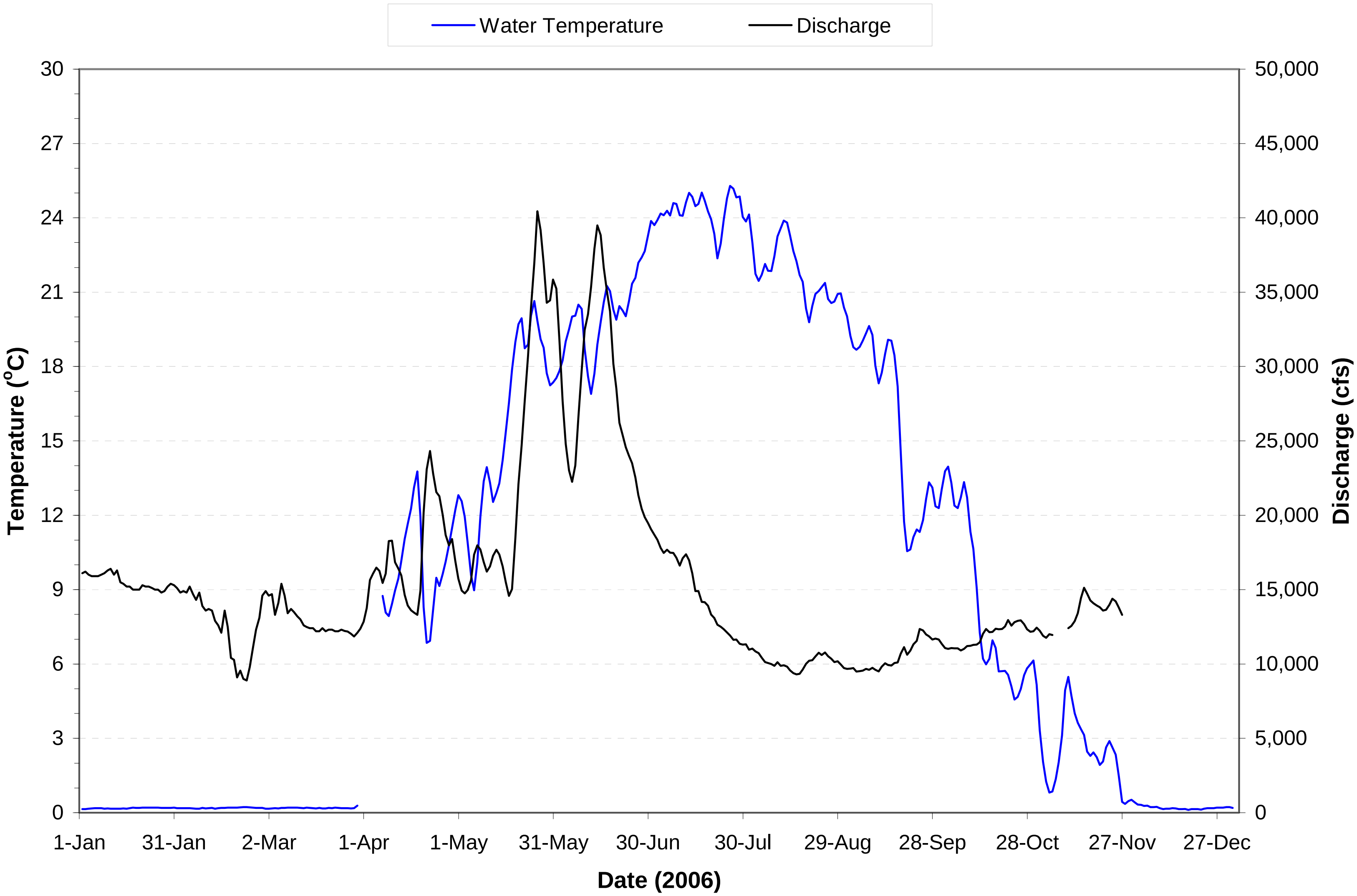


Plate 92. Mean daily water temperature and discharge of the Missouri River near Williston, North Dakota (i.e., site GARNFMORRR1) for 2006. Mean temperatures based on hourly measurements recorded on the Missouri River near Williston, North Dakota (USGS gaging station 06330000). Mean daily discharge estimated by adding mean daily discharge recorded for the Missouri River near Culbertson, Montana (USGS gaging station 06185500) and the mean daily discharge recorded for the Yellowstone River near Sidney, Montana (USGS gaging station 06329500).

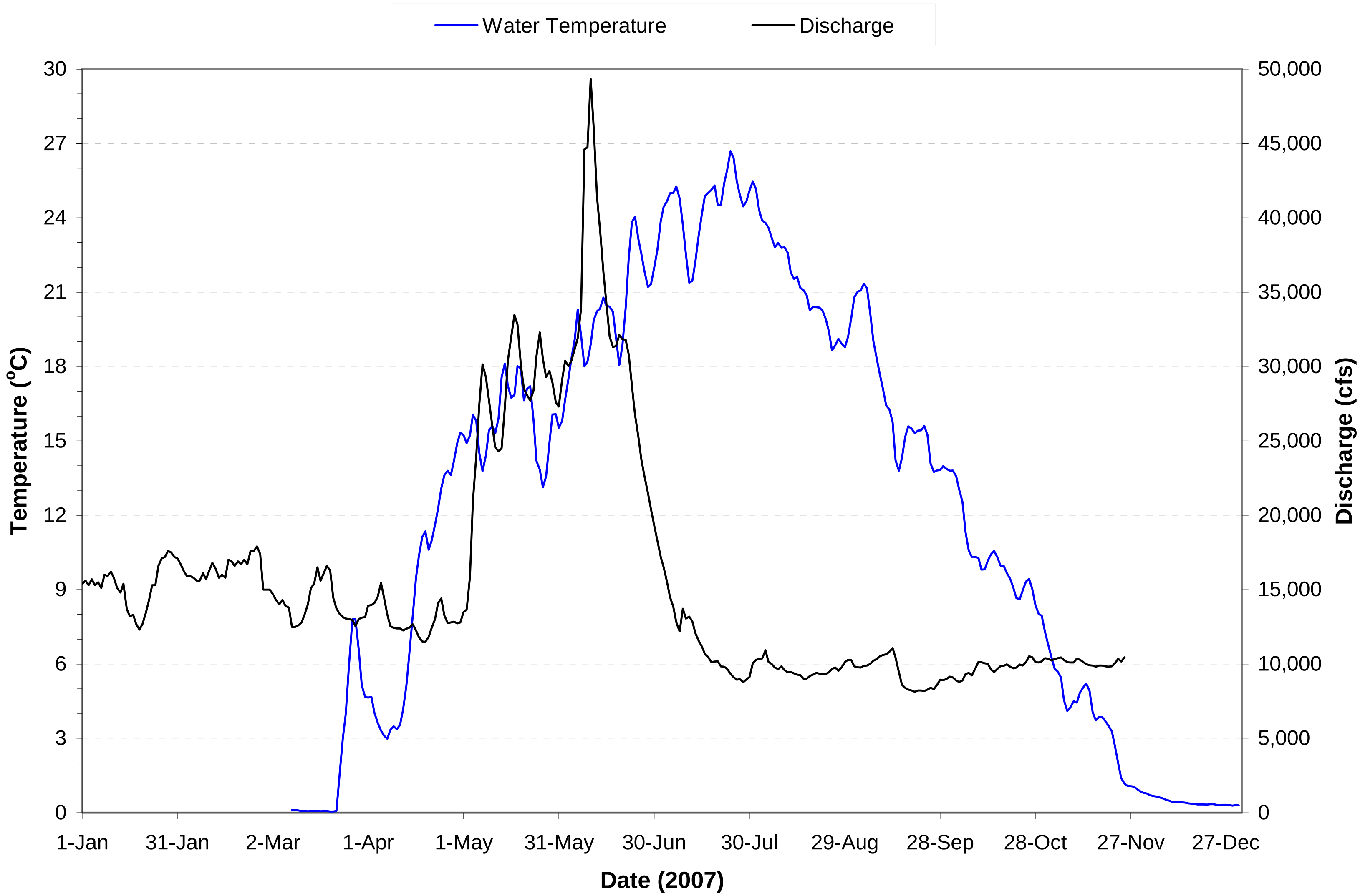


Plate 93. Mean daily water temperature and discharge of the Missouri River near Williston, North Dakota (i.e., site GARNFMORRR1) for 2007. Mean temperatures based on hourly measurements recorded on the Missouri River near Williston, North Dakota (USGS gaging station 06330000). Mean daily discharge estimated by adding mean daily discharge recorded for the Missouri River near Culbertson, Montana (USGS gaging station 06185500) and the mean daily discharge recorded for the Yellowstone River near Sidney, Montana (USGS gaging station 06329500).

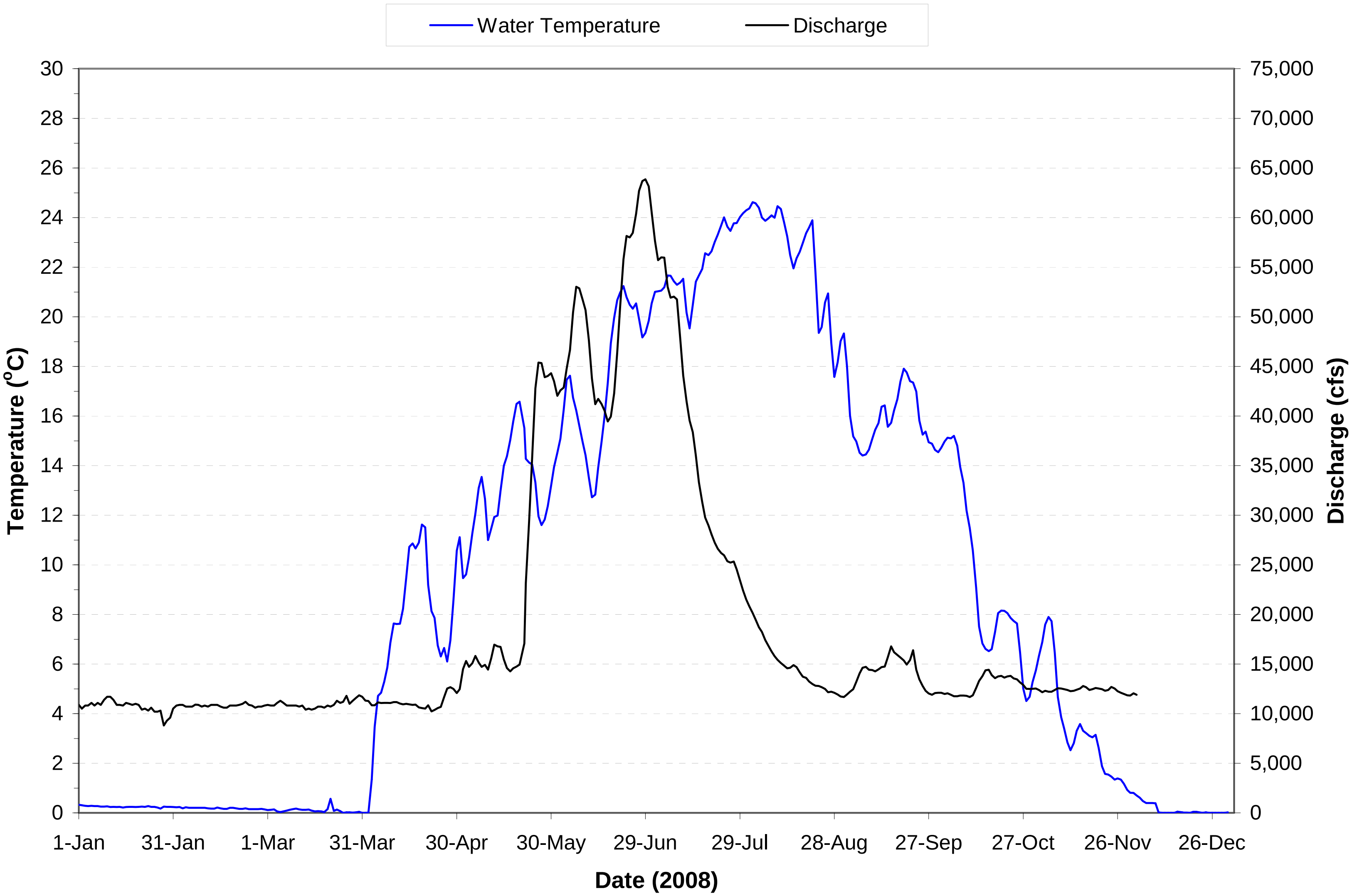


Plate 94. Mean daily water temperature and discharge of the Missouri River near Williston, North Dakota (i.e., site GARNFMORRR1) for 2008. Mean temperatures based on hourly measurements recorded on the Missouri River near Williston, North Dakota (USGS gaging station 06330000). Mean daily discharge estimated by adding mean daily discharge recorded for the Missouri River near Culbertson, Montana (USGS gaging station 06185500) and the mean daily discharge recorded for the Yellowstone River near Sidney, Montana (USGS gaging station 06329500).

Plate 95. Summary of water quality conditions monitored on water discharged through Garrison Dam (i.e., site GARPP1) during the 5-year period 2004 through 2008.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit[A]	No. of Obs.	Mean[B]	Median	Min.	Max.	State WQS Criteria[C]	No. of WQS Exceedences	Percent WQS Exceedence
Dam Discharge (cfs)	1	50	15,865	14,006	9,450	37,300	-----	-----	-----
Water Temperature (C)	0.1	45	8.9	8.5	1.0	18.2	29.4[1,2]	0	0%
Dissolved Oxygen (mg/l)	0.1	44	8.9	10.3	4.4	14.2	5.0[1,3]	1	2%
Dissolved Oxygen (% Sat.)	0.1	44	87.2	92.3	44.6	105.6	-----	-----	-----
pH (S.U.)	0.1	40	8.2	8.2	7.4	8.9	7.0[1,3], 9.0[1,2]	0	0%
Specific Conductance (umho/cm)	1	42	583	593	481	651	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	28	407	379	316	597	-----	-----	-----
Turbidity (NTU)	1	23	5	2	n.d.	19	-----	-----	-----
Alkalinity, Total (mg/l)	7	48	163	161	140	186	-----	-----	-----
Ammonia, Total (mg/l)	0.02	48	-----	n.d.	n.d.	0 52	5.73[1,2,4], 1.71[1,4,5]	0	0%
Carbon, Total Organic (mg/l)	0.05	46	3.2	3.1	1.3	7.5	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	31	6	7	n.d.	16	-----	-----	-----
Chloride, Dissolved (mg/l)	1	28	9	10	8	11	100[1,2]	0	0%
Dissolved Solids, Total (mg/l)	5	48	412	410	236	516	-----	-----	-----
Hardness, Total (mg/l)	0.4	6	207	208	186	223	-----	-----	-----
Iron, Total (ug/l)	40	31	196	102	n.d.	1,401	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	47	0.5	0.3	n.d.	2.4	-----	-----	-----
Manganese, Total (ug/l)	2	31	10	7	n.d.	64	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	48	-----	0.06	n.d.	0 15	1.0[1,2]	0	0%
Phosphorus, Dissolved (mg/l)	0.02	39	-----	n.d.	n.d.	0 14	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	48	-----	0.02	n.d.	0 30	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	48	-----	n.d.	n.d.	0 25	-----	-----	-----
Sulfate (mg/l)	1	48	163	163	128	190	250[1,2]	0	0%
Suspended Solids, Total (mg/l)	4	48	-----	n.d.	n.d.	21	-----	-----	-----
Aluminum, Dissolved (ug/l)	25	3	-----	n.d.	n.d.	n.d.	-----	-----	-----
Aluminum, Total (ug/l)	25	2	77	77	60	94	750[6]	0	0%
Antimony, Total (ug/l)	0.5	2	-----	n.d.	n.d.	n.d.	5.6[8]	0	0%
Arsenic, Total (ug/l)	1	2	-----	n.d.	n.d.	n.d.	340[6], 150[7], 10[8]	0	0%
Barium, Total (ug/l)	5	2	56	56	52	60	1,000[8]	0	0%
Beryllium, Total (ug/l)	2	2	-----	n.d.	n.d.	n.d.	4[8]	0	0%
Cadmium, Total (ug/l)	0.2	2	-----	n.d.	n.d.	n.d.	4.5[6], 0.5[7], 5[8]	0	0%
Chromium, Total (ug/l)	10	2	-----	n.d.	n.d.	n.d.	3,285[6], 157[7], 100[8]	0	0%
Copper, Total (ug/l)	2	2	-----	n.d.	n.d.	n.d.	28[6], 17[7], 1,000[8]	0	0%
Lead, Total (ug/l)	0.5	2	-----	n.d.	n.d.	0.7	207[6], 8.1[7], 15[8]	0	0%
Mercury, Total (ug/l)	0.02	7	-----	n.d.	n.d.	n.d.	1.7[6], 0.012[7], 0.05[8]	0, b.d., 0	0%, b.d., 0%
Nickel, Total (ug/l)	10	2	-----	n.d.	n.d.	n.d.	861[6], 96[7], 100[8]	0	0%
Selenium, Total (ug/l)	1	6	-----	n.d.	n.d.	2	20[6], 5[7], 50[8]	0	0%
Silver, Total (ug/l)	1	2	-----	n.d.	n.d.	n.d.	14[6]	0	0%
Thallium, Total (ug/l)	0.5	2	-----	n.d.	n.d.	n.d.	0.24[8]	b.d.	b.d.
Zinc, Total (ug/l)	10	2	-----	n.d.	n.d.	n.d.	223[6,7], 7,400[8]	0	0%
Pesticide Scan (ug/l)[D]	0.05	4	-----	n.d.	n.d.	n.d.	-----	-----	-----

n.d. = Not detected. b.d. = Criterion below detection limit.

(A) Detection limits given for the parameters Stream Flow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

(1) Criteria for Class 1 streams.
(2) Daily maximum criterion (monitoring results directly comparable to criterion).
(3) Daily minimum criterion (monitoring results directly comparable to criterion).
(4) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
(5) 30-day average criterion (monitoring results not directly comparable to criterion).
(6) Acute criterion for aquatic life.
(7) Chronic criterion for aquatic life.
(8) Human health criterion for surface waters.

Note: Some of North Dakota's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

(D) The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, cycloate, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, isopropalin, metolachlor, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, phorate, profluralin, prometon, propachlor, propazine, simazine, terbufos, triallate, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

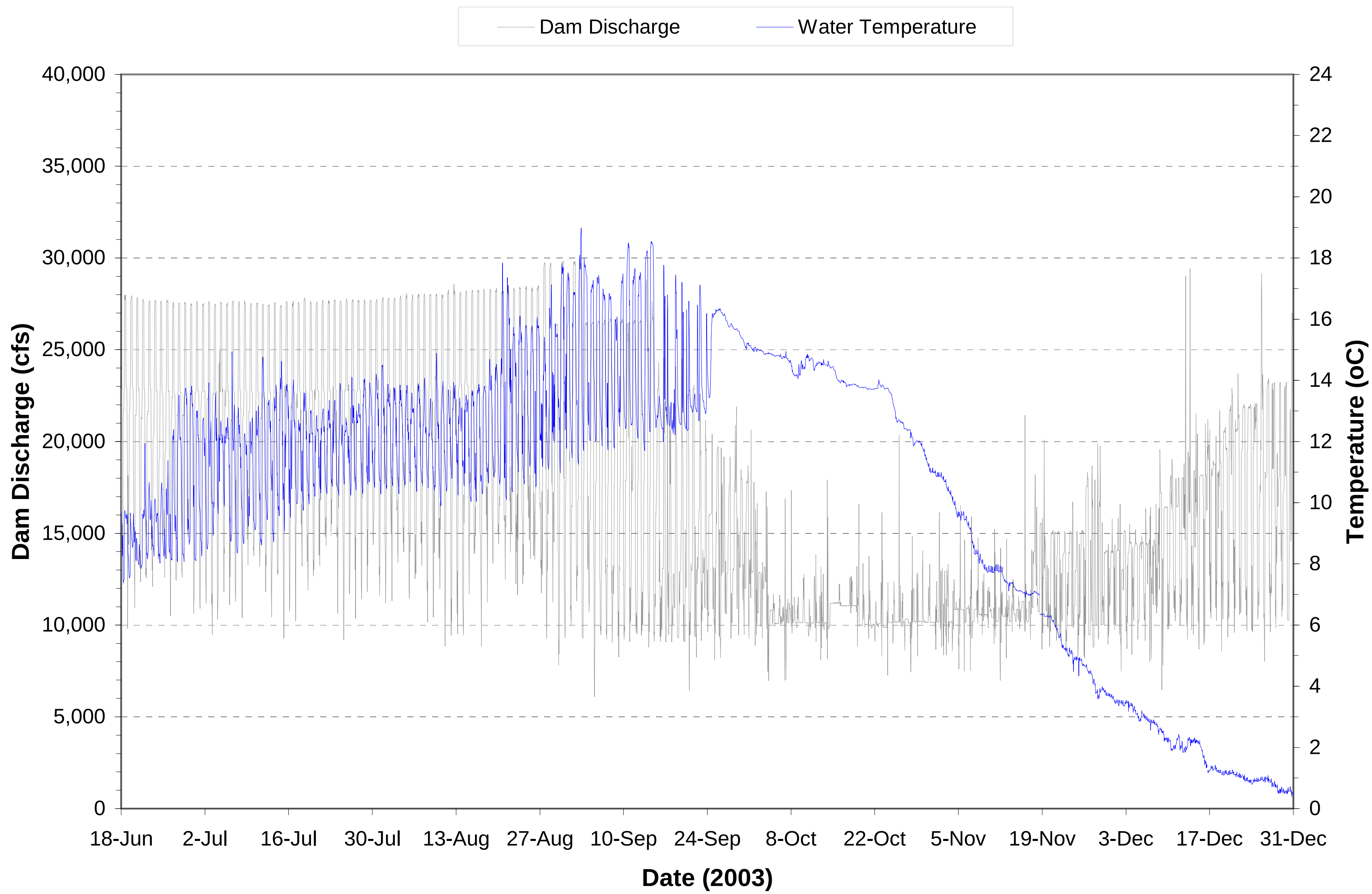


Plate 96. Hourly discharge and water temperature monitored at the Garrison powerplant on water discharged through the dam during the period June through December 2003.

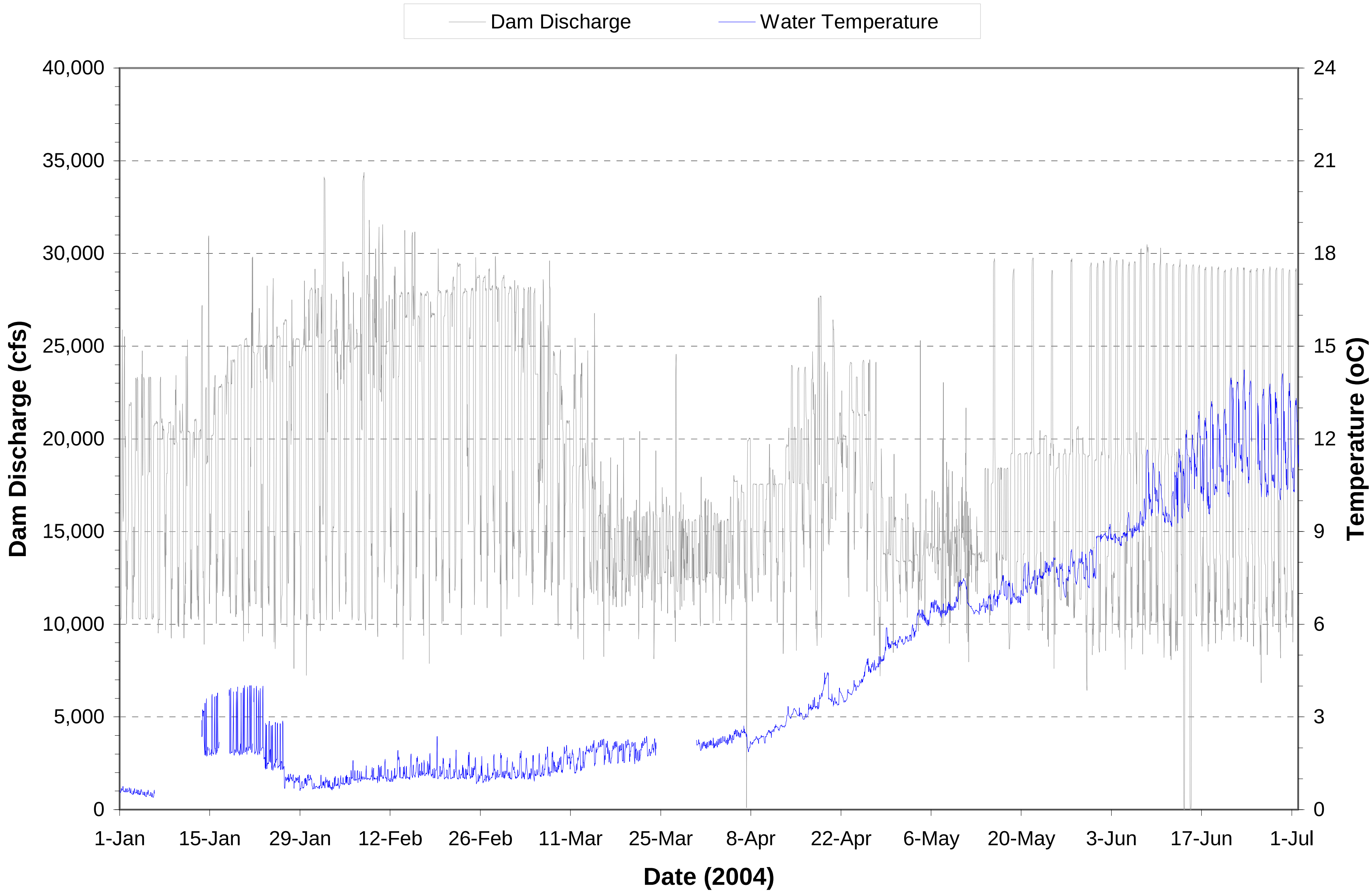


Plate 97. Hourly discharge and water temperature monitored at the Garrison powerplant on water discharged through the dam during the period January through June 2004.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

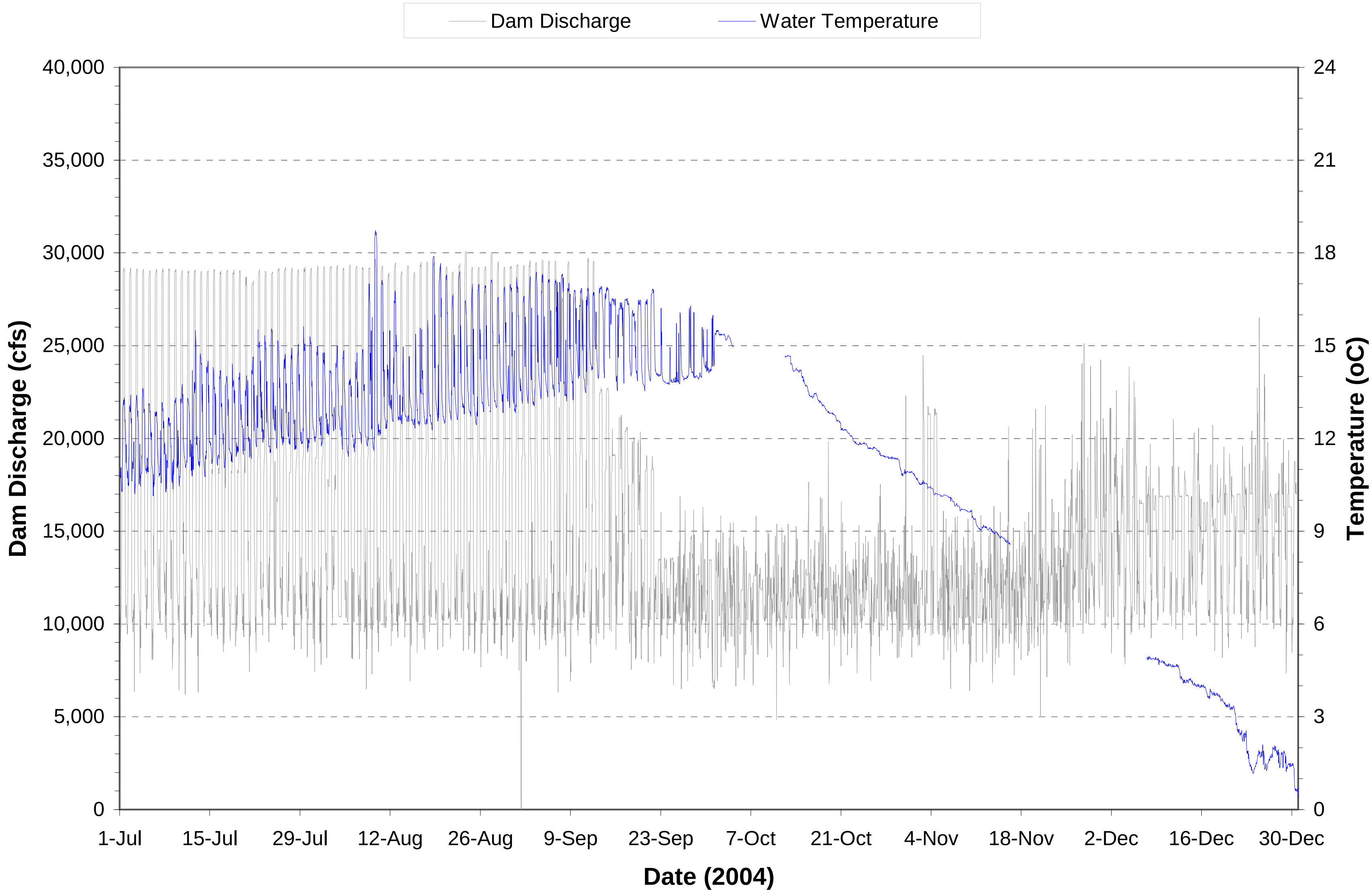


Plate 98. Hourly discharge and water temperature monitored at the Garrison powerplant on water discharged through the dam during the period July through December 2004.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

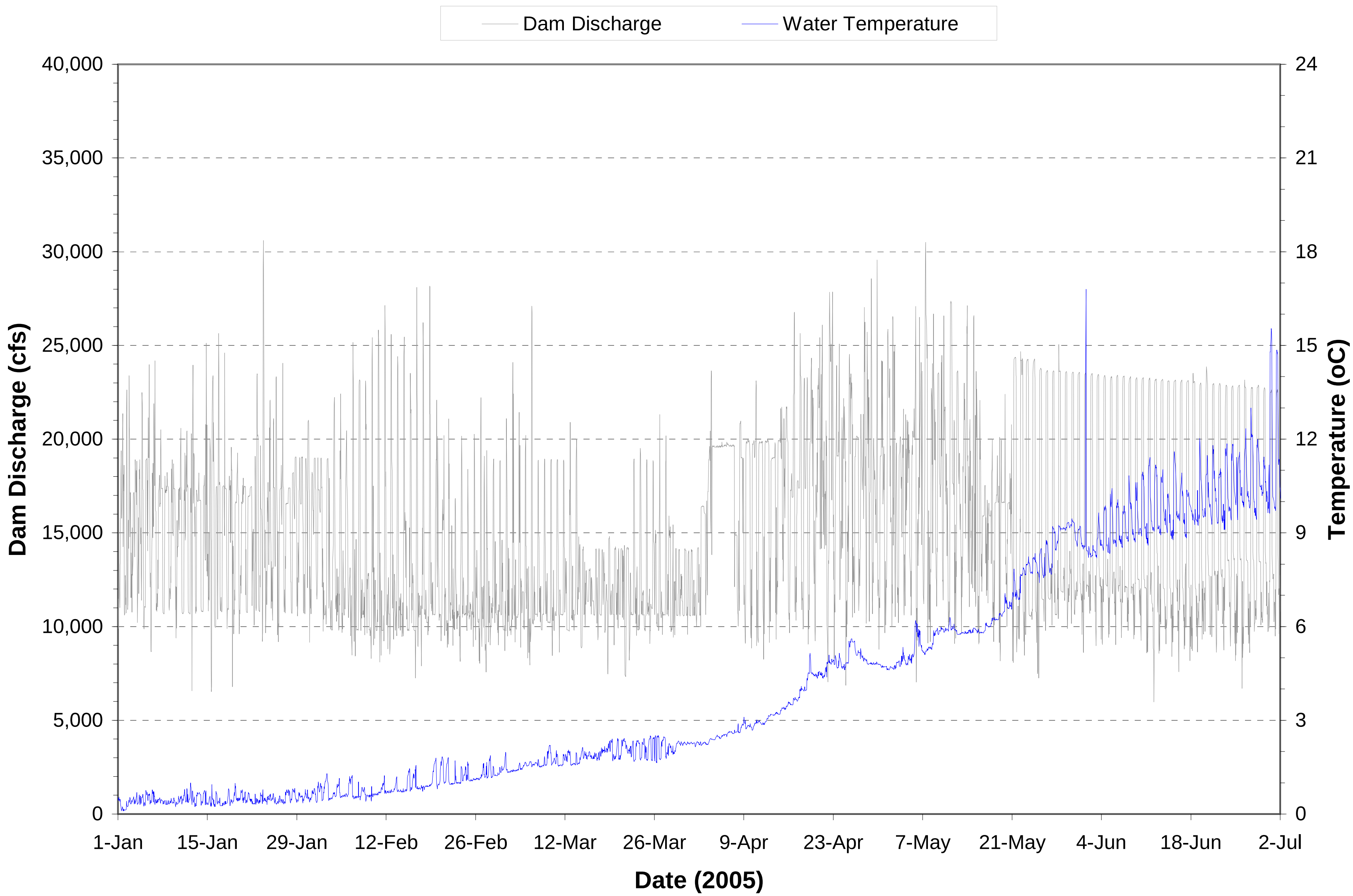


Plate 99. Hourly discharge and water temperature monitored at the Garrison powerplant on water discharged through the dam during the period January through June 2005.

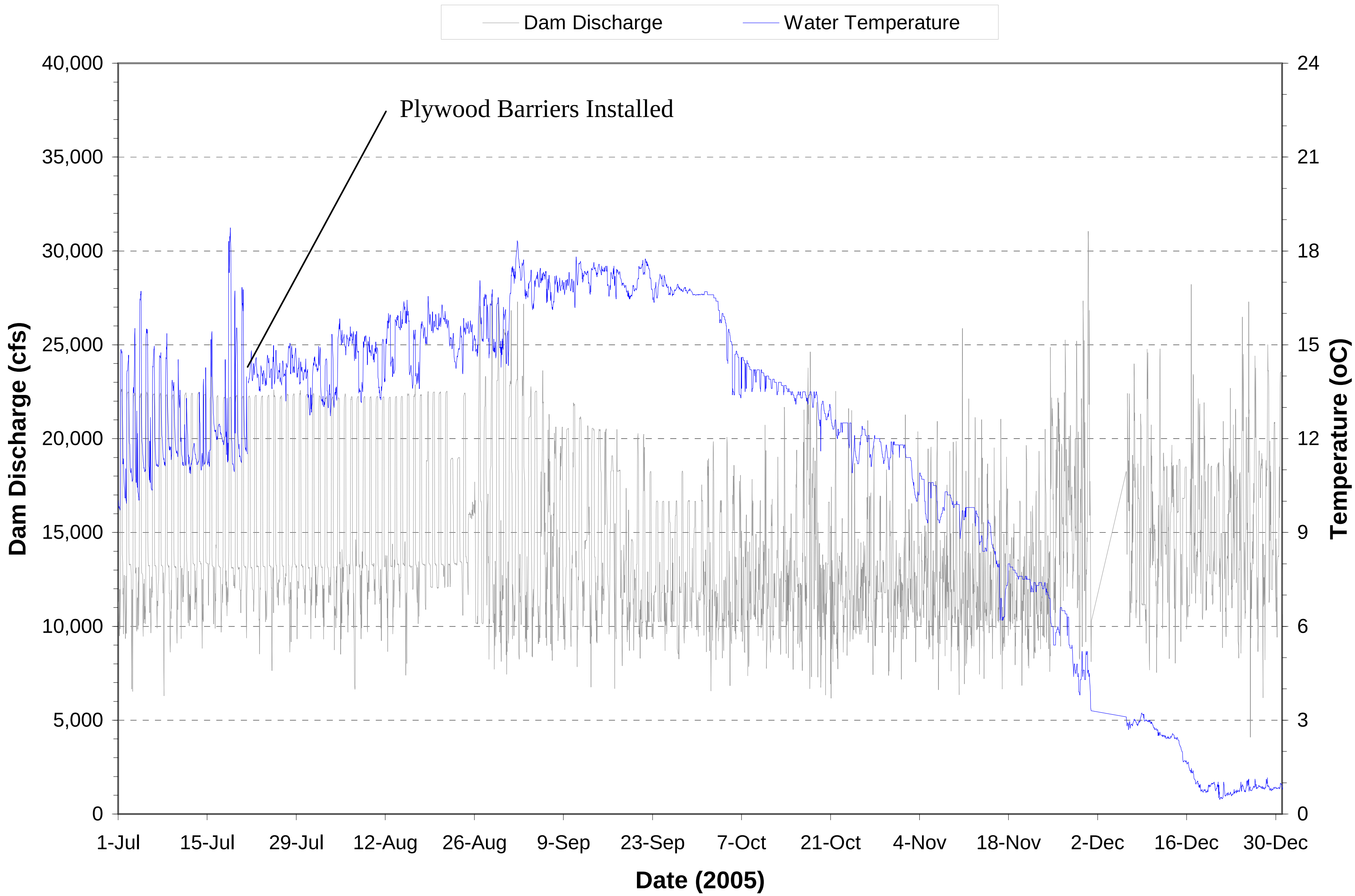


Plate 100. Hourly discharge and water temperature monitored at the Garrison powerplant on water discharged through the dam during the period July through December 2005.

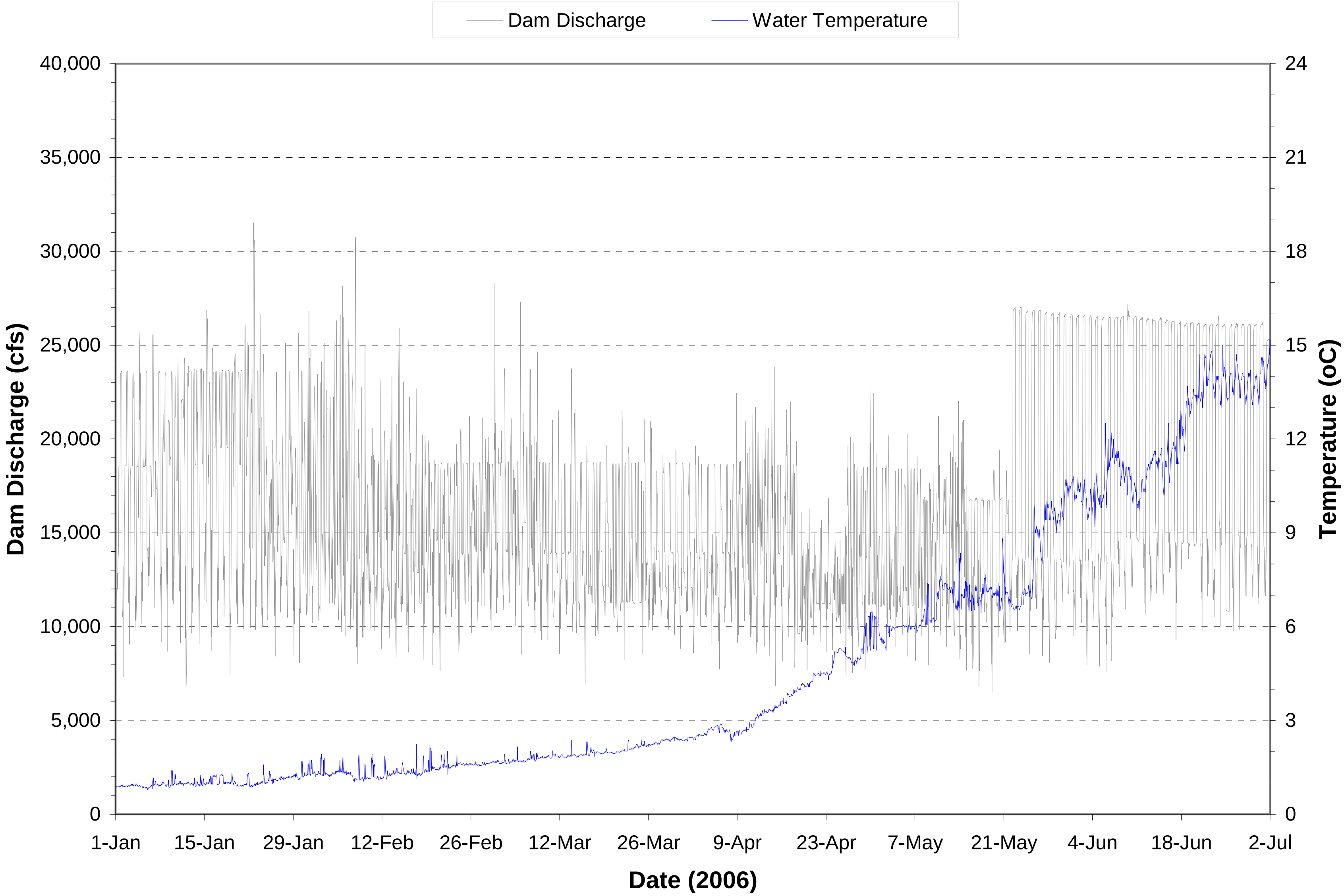


Plate 101. Hourly discharge and water temperature monitored at the Garrison powerplant on water discharged through the dam during the period January through June 2006.

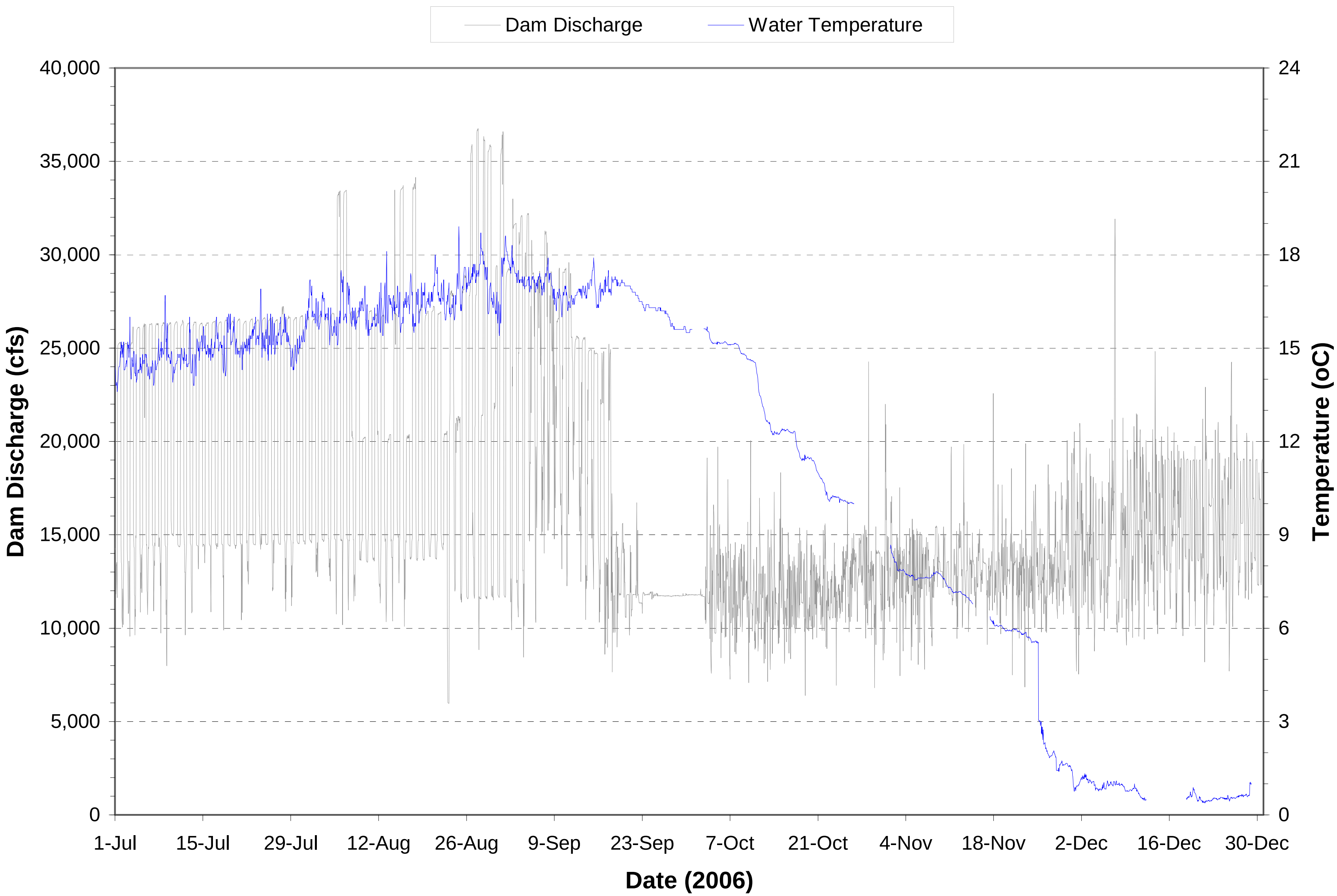


Plate 102. Hourly discharge and water temperature monitored at the Garrison powerplant on water discharged through the dam during the period July through December 2006.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

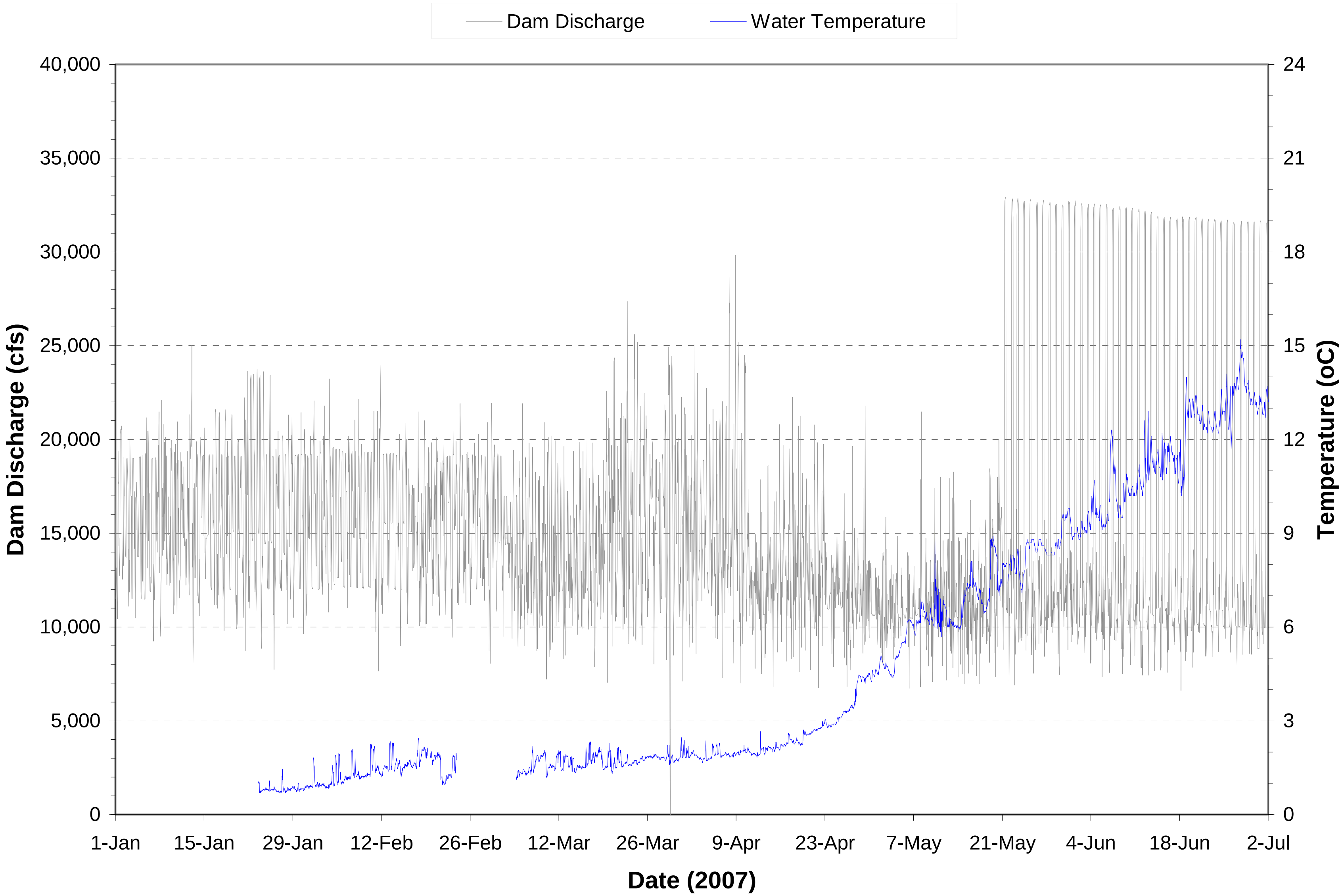


Plate 103. Hourly discharge and water temperature monitored at the Garrison powerplant on water discharged through the dam during the period January through June 2007.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

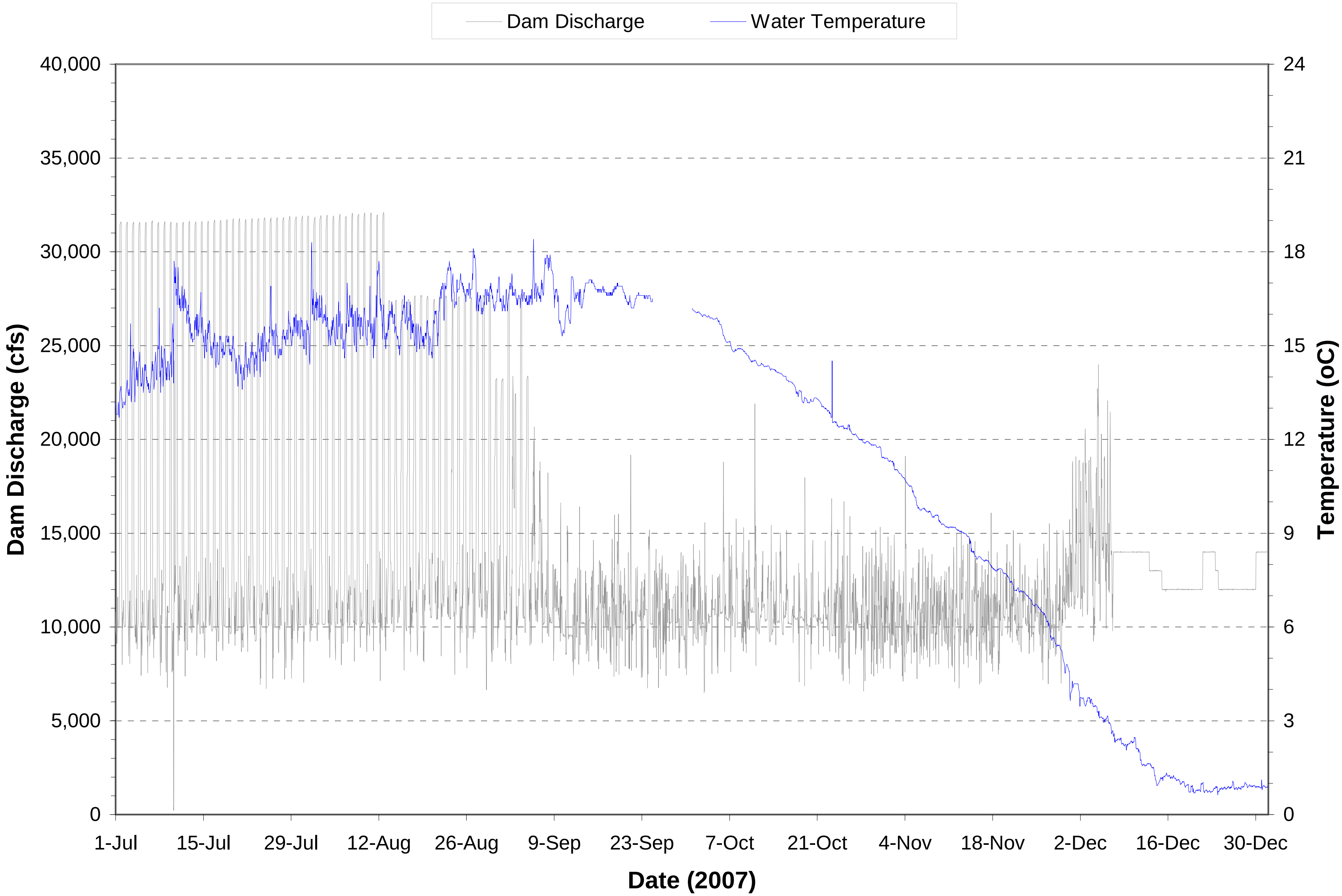


Plate 104. Hourly discharge and water temperature monitored at the Garrison powerplant on water discharged through the dam during the period July through December 2007.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

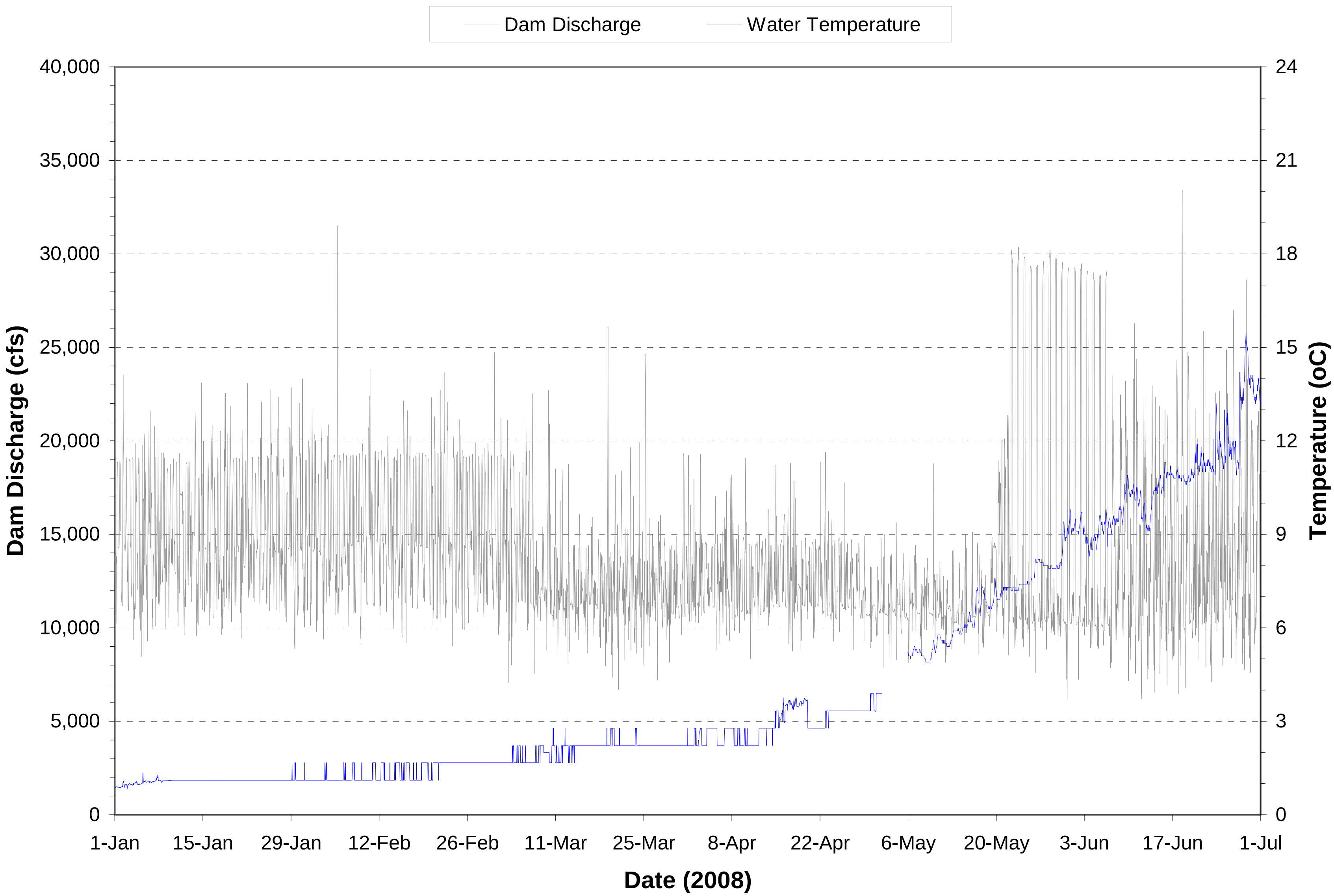


Plate 105. Hourly discharge and water temperature monitored at the Garrison powerplant on water discharged through the dam during the period January through June 2008.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

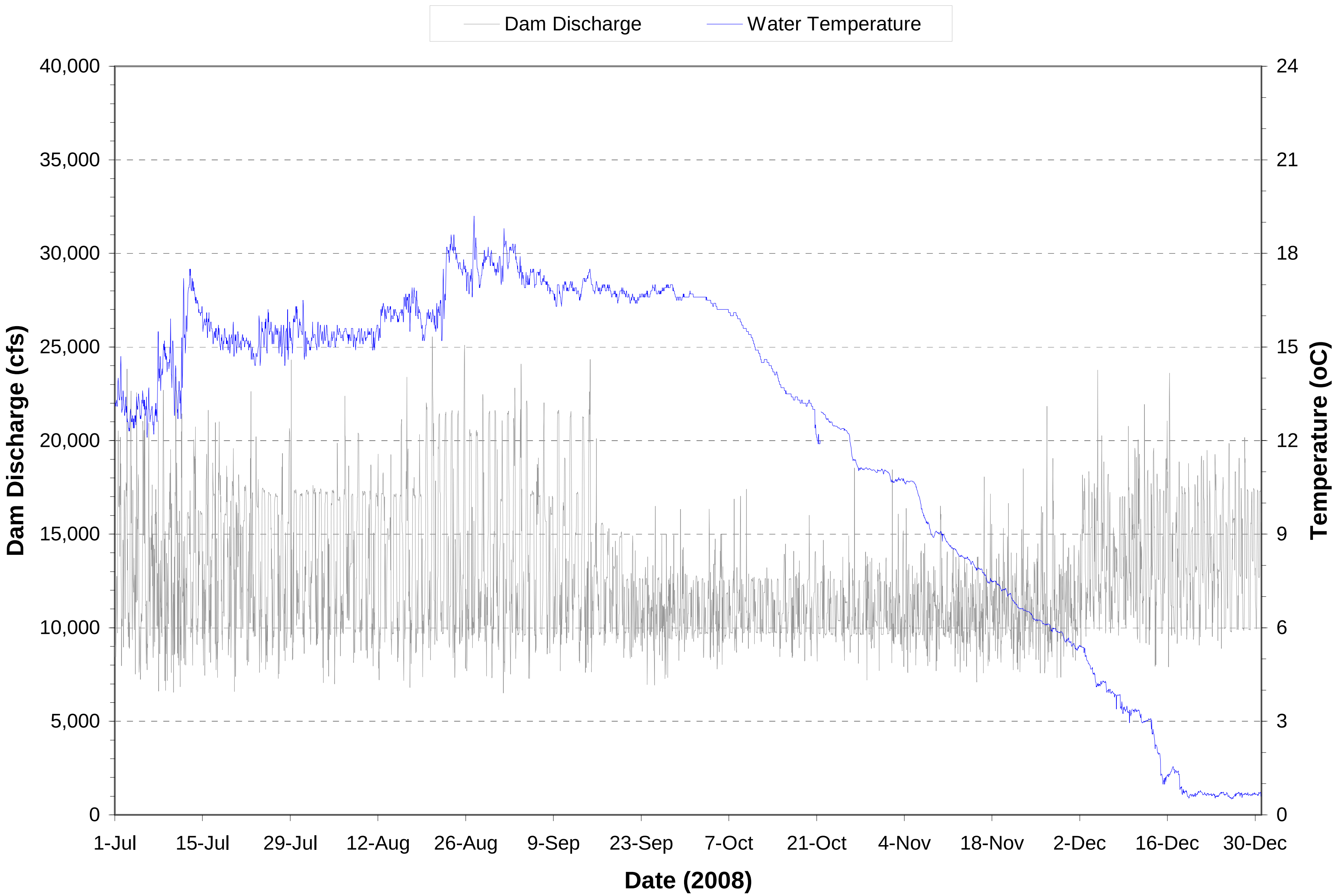


Plate 106. Hourly discharge and water temperature monitored at the Garrison powerplant on water discharged through the dam during the period July through December 2008.

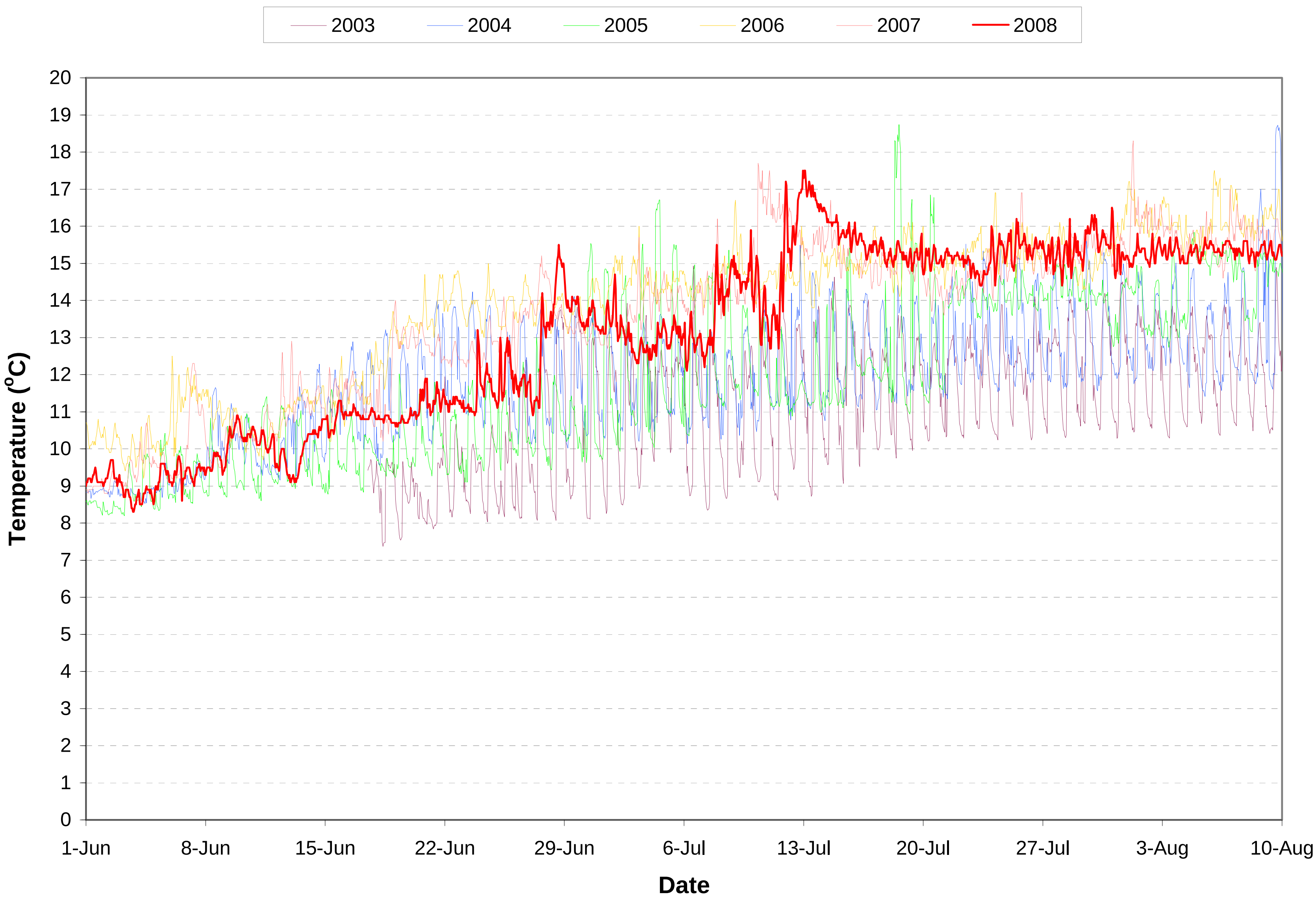


Plate 107. Hourly temperature of water discharged through Garrison Dam during the period June 1 through Mid-August in 2003, 2004, 2005, 2006, 2007, and 2008.

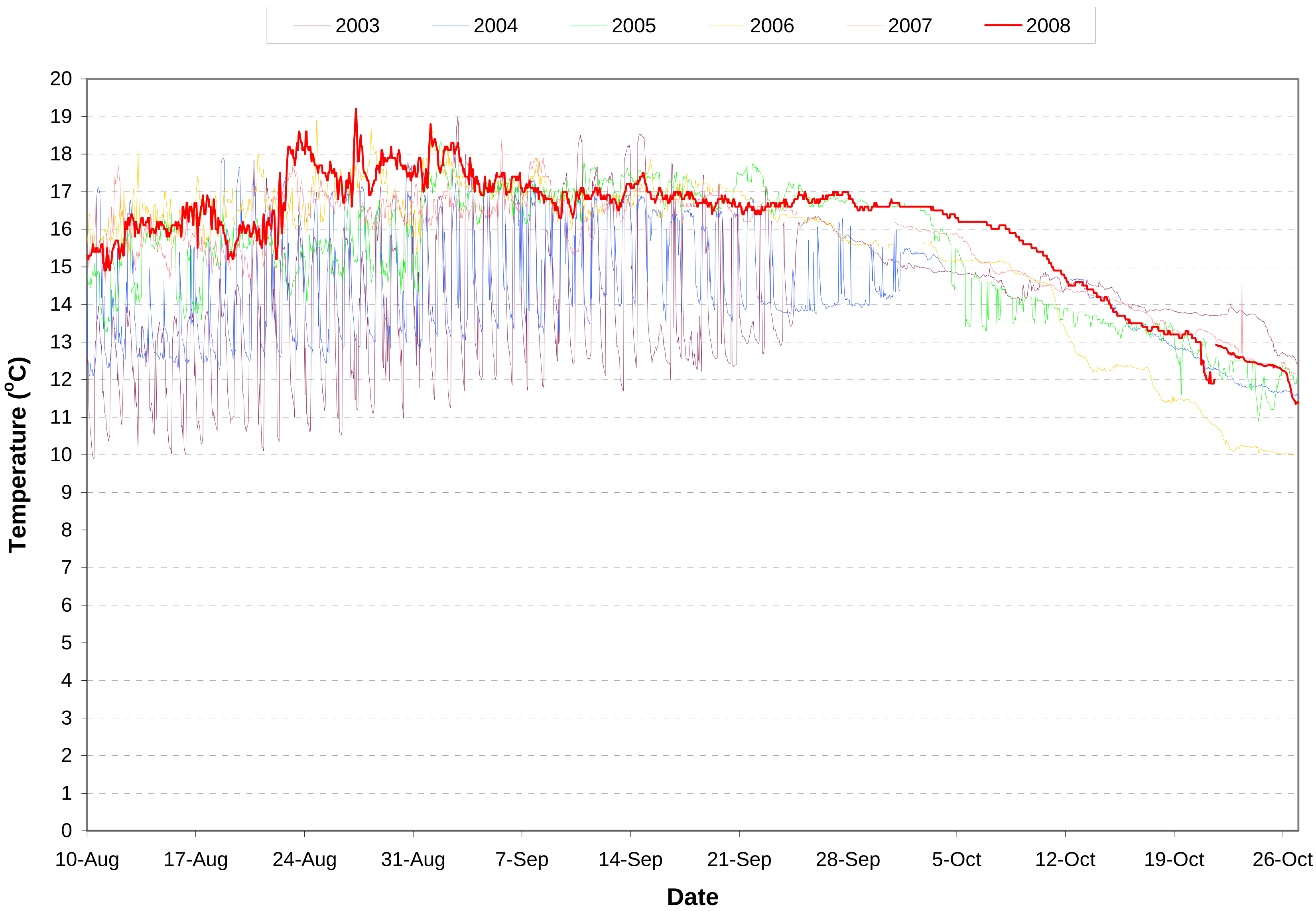


Plate 108. Hourly temperature of water discharged through Garrison Dam during the period Mid-August through October in 2003, 2004, 2005, 2006, 2007, and 2008.

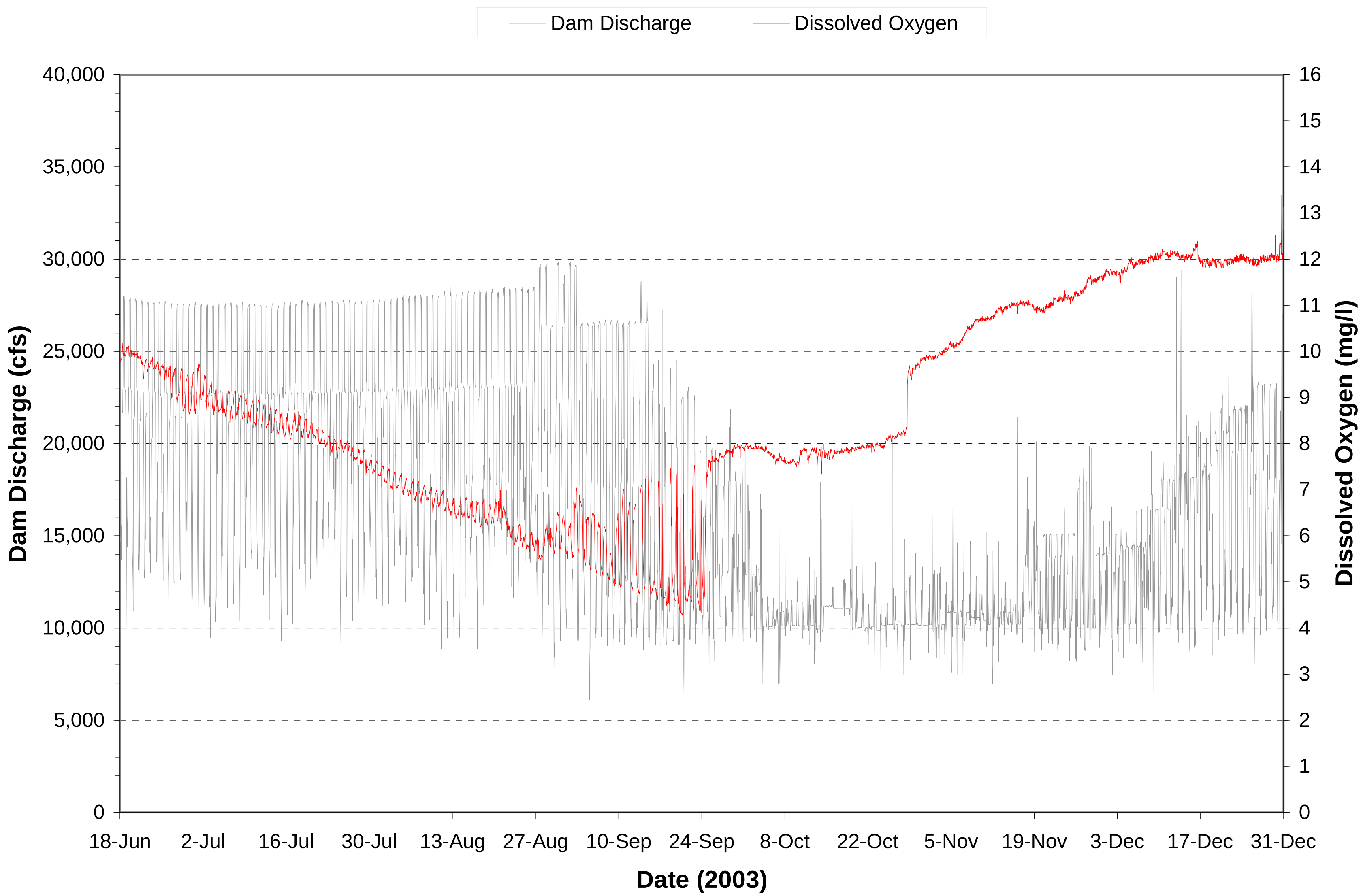


Plate 109. Hourly discharge and dissolved oxygen monitored at the Garrison powerplant on water discharged through the dam during the period June through December 2003.

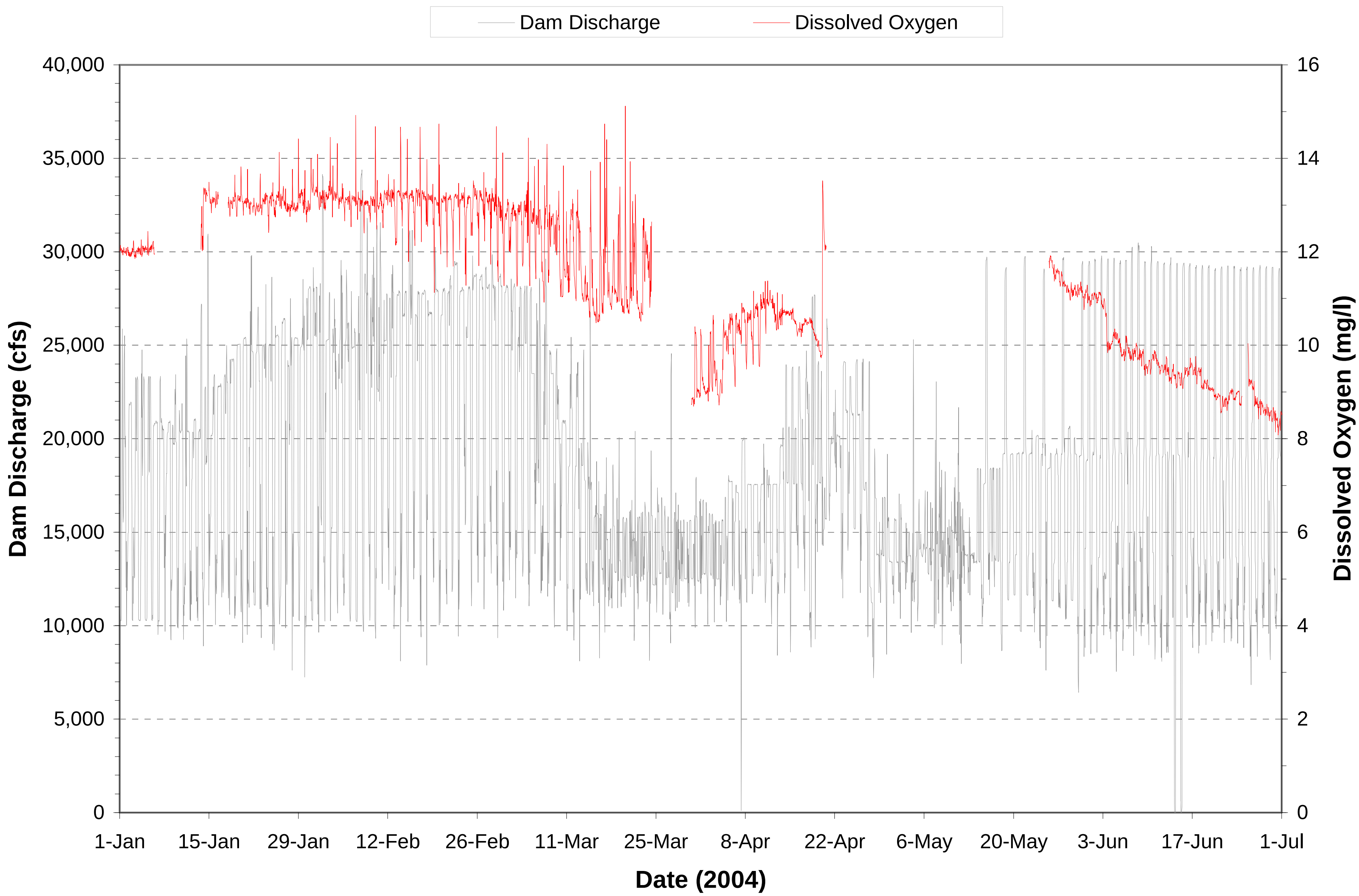


Plate 110. Hourly discharge and dissolved oxygen monitored at the Garrison powerplant on water discharged through the dam during the period January through June 2004.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

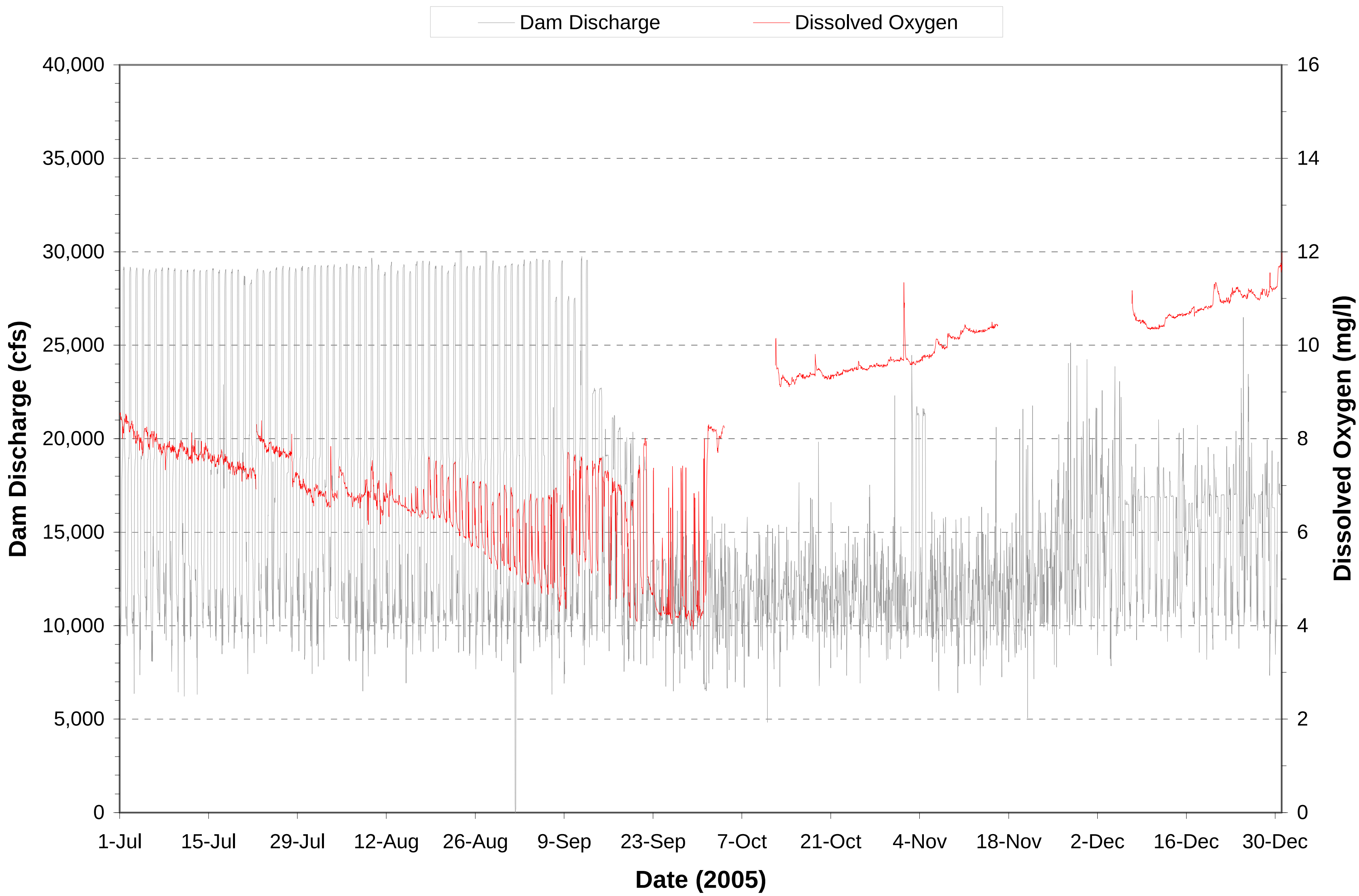


Plate 111. Hourly discharge and dissolved oxygen monitored at the Garrison powerplant on water discharged through the dam during the period July through December 2004.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

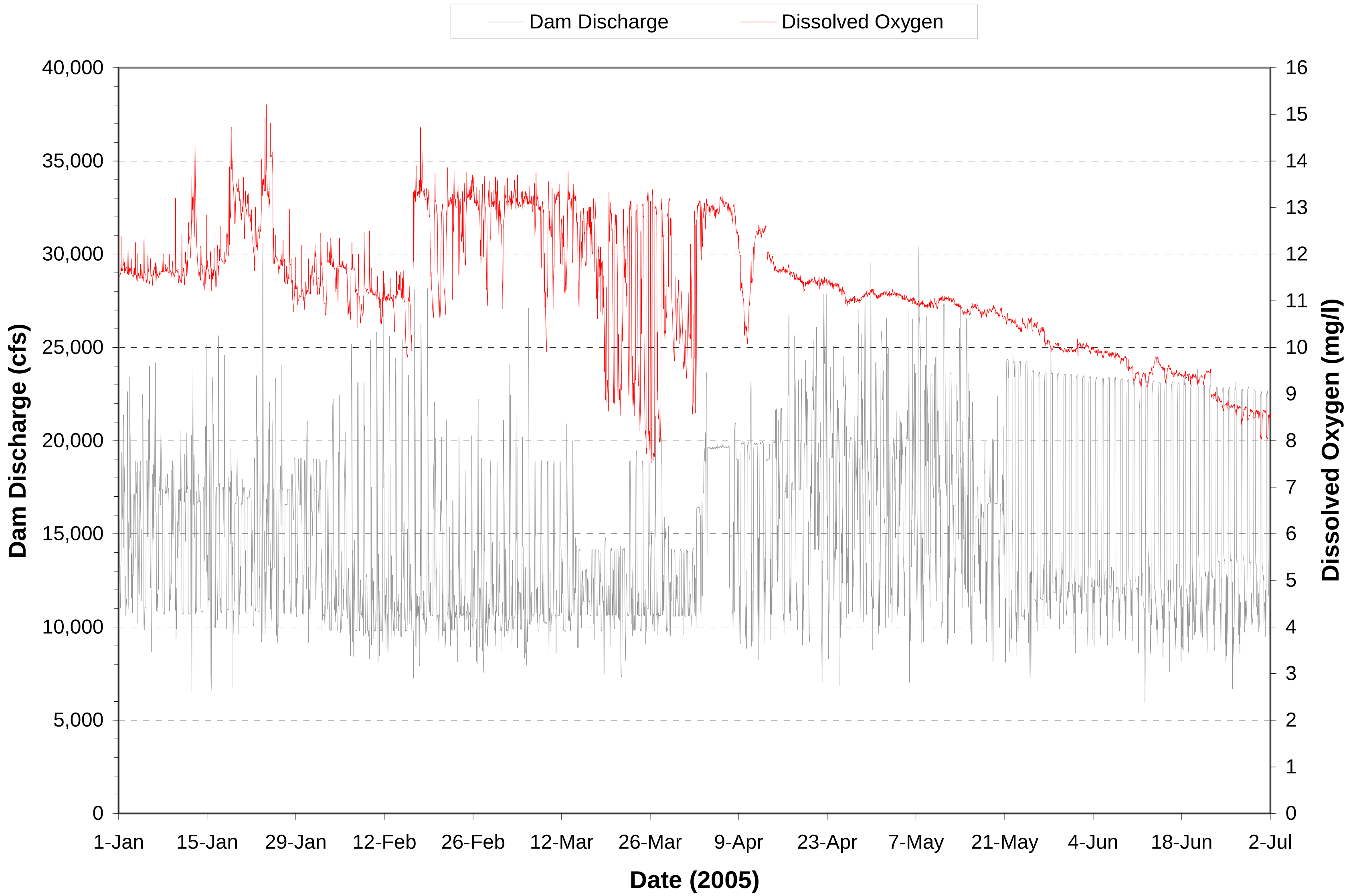


Plate 112. Hourly discharge and dissolved oxygen monitored at the Garrison powerplant on water discharged through the dam during the period January through June 2005.

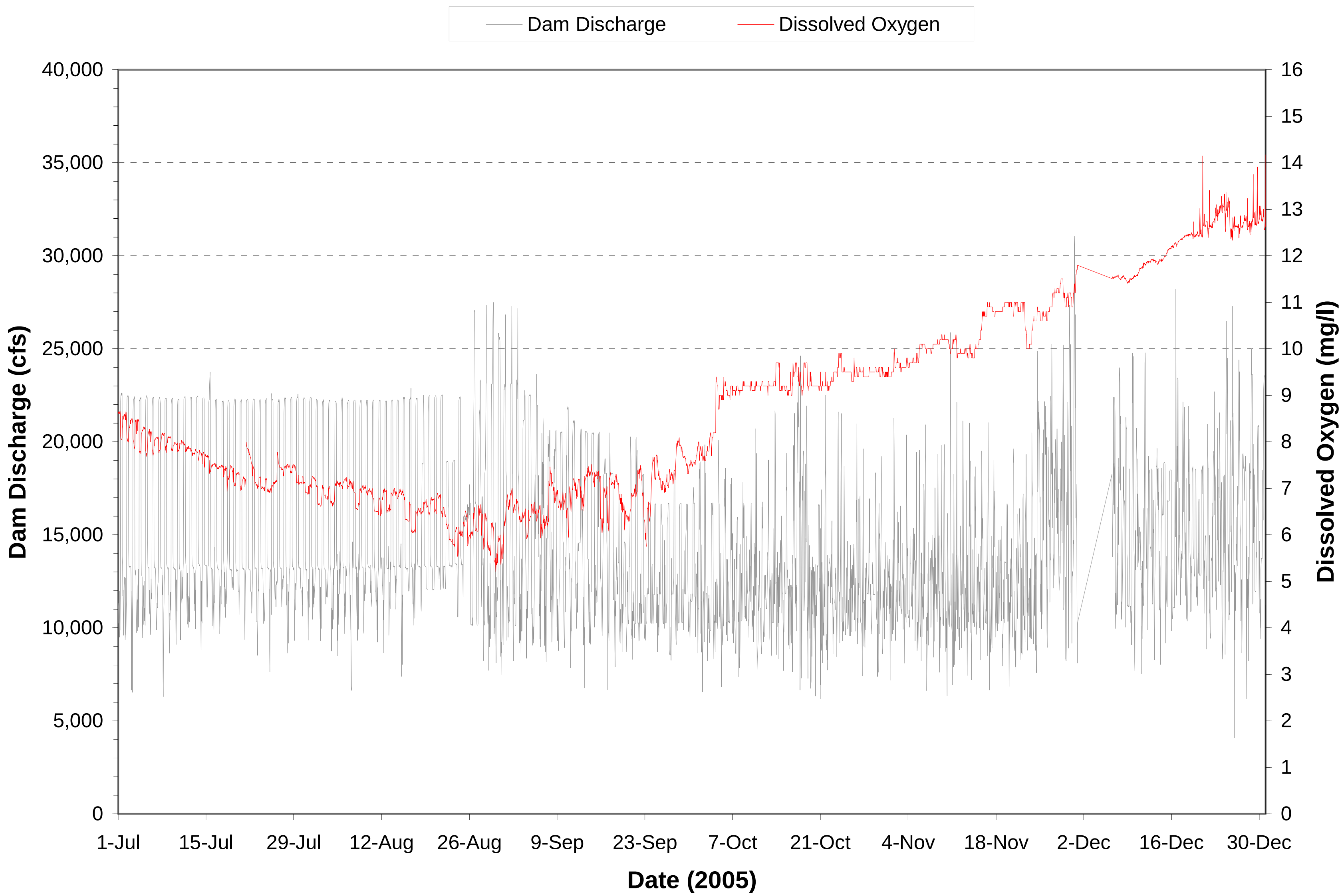


Plate 113. Hourly discharge and dissolved oxygen monitored at the Garrison powerplant on water discharged through the dam during the period July through December 2005.

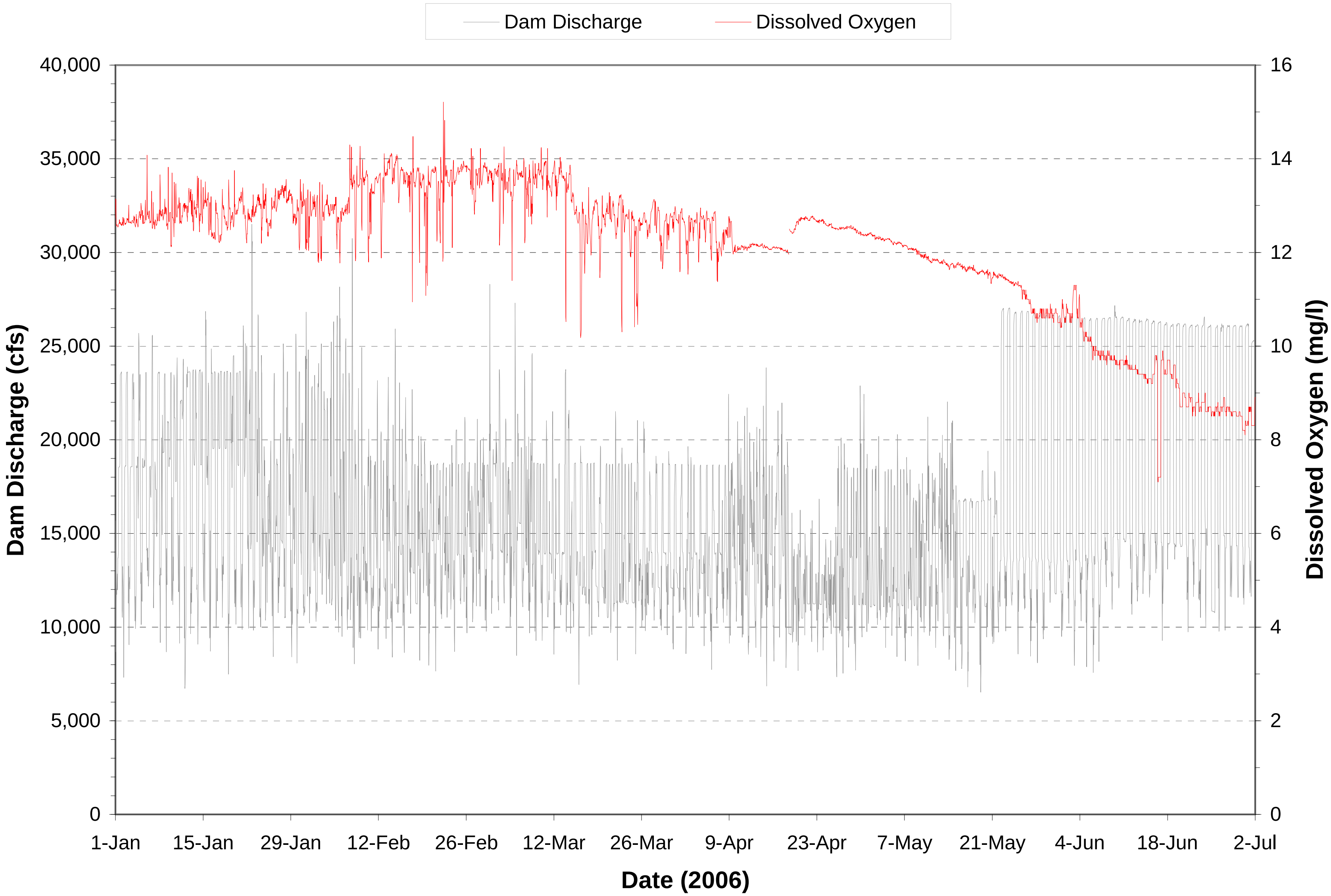


Plate 114. Hourly discharge and dissolved oxygen monitored at the Garrison powerplant on water discharged through the dam during the period January through June 2006.

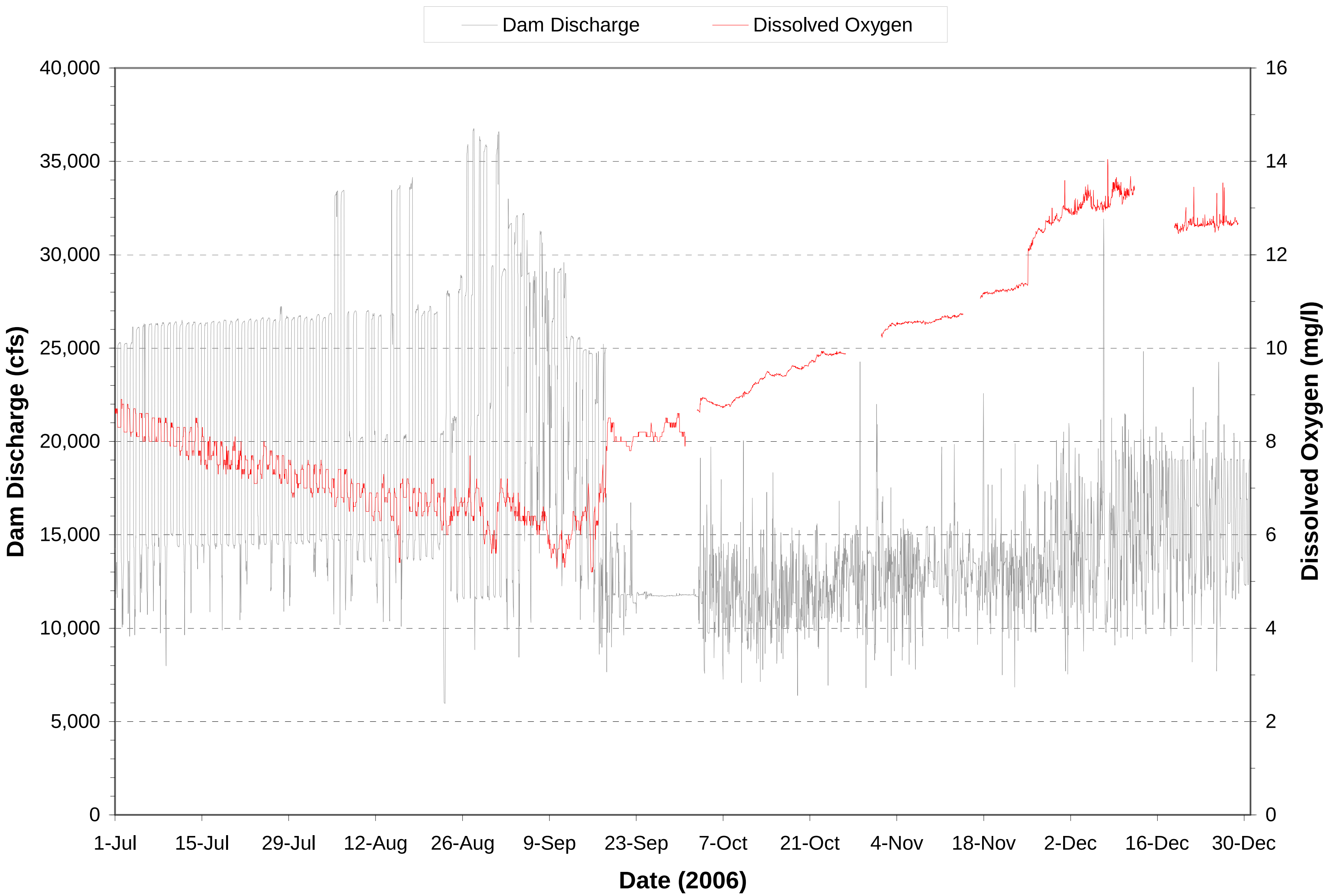


Plate 115. Hourly discharge and dissolved oxygen monitored at the Garrison powerplant on water discharged through the dam during the period July through December 2006.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

Plate 116. Hourly discharge and dissolved oxygen monitored at the Garrison powerplant on water discharged through the dam during the period January through June 2007.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

Plate 117. Hourly discharge and dissolved oxygen monitored at the Garrison powerplant on water discharged through the dam during the period July through December 2007.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

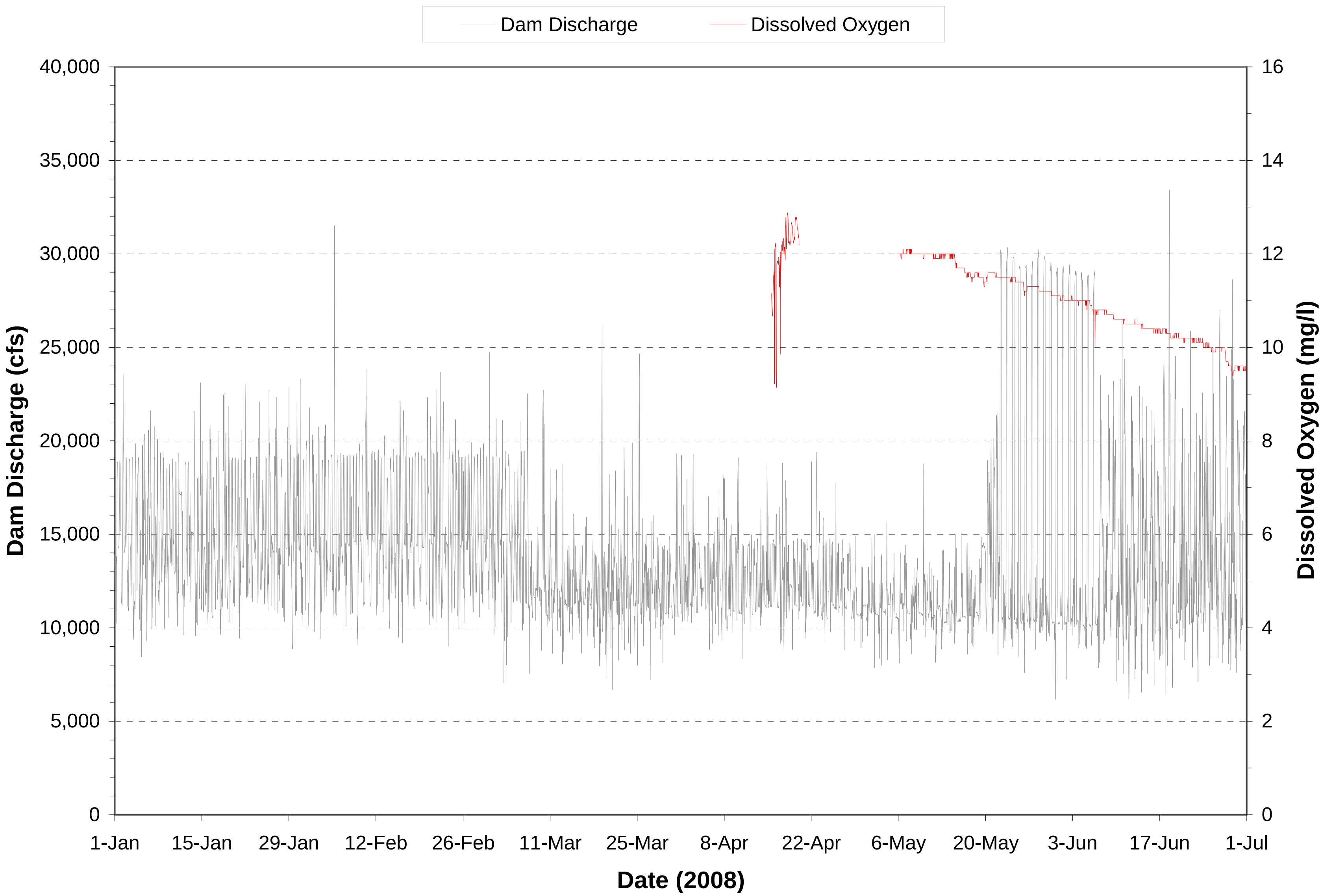


Plate 118. Hourly discharge and dissolved oxygen monitored at the Garrison powerplant on water discharged through the dam during the period January through June 2008.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

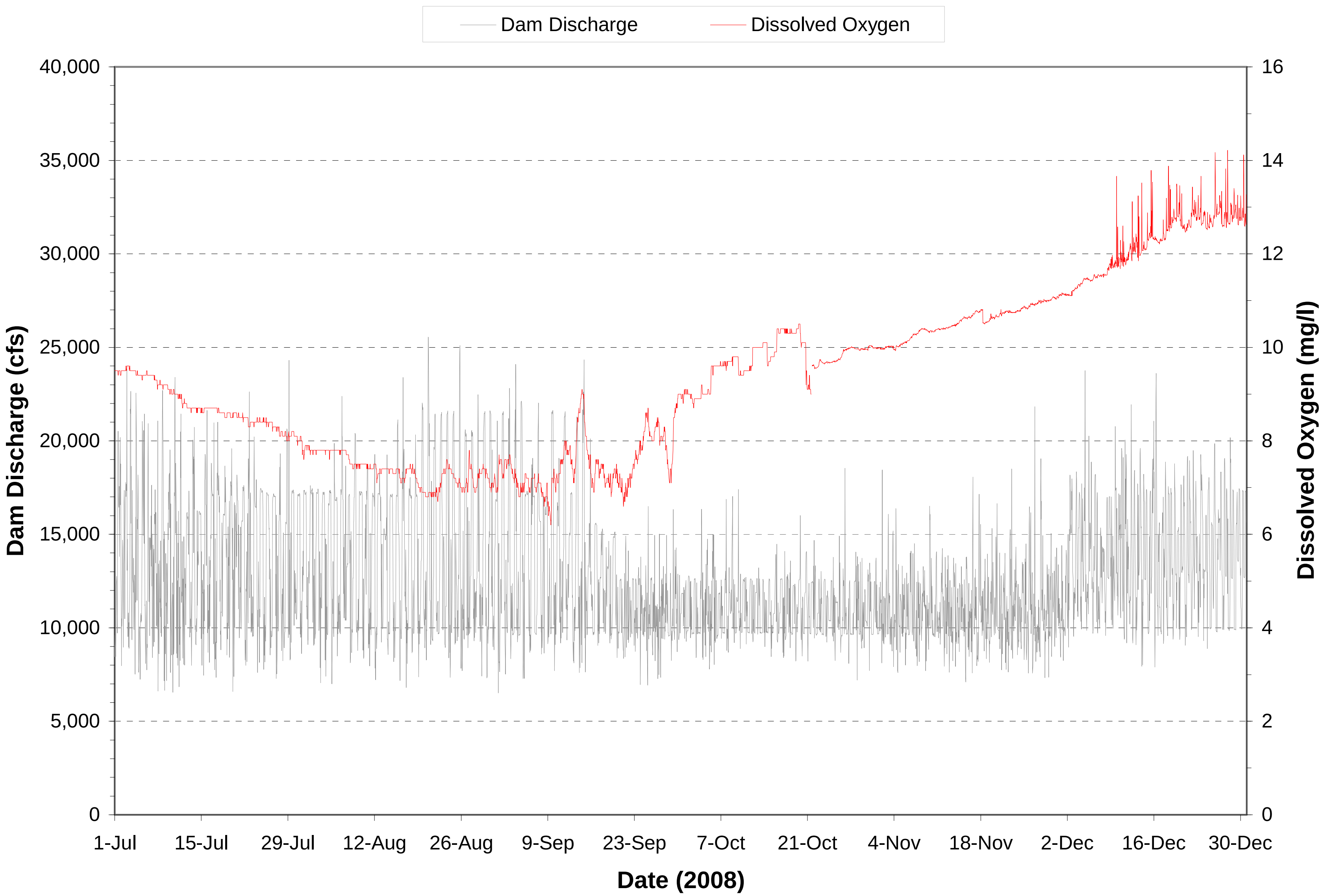


Plate 119. Hourly discharge and dissolved oxygen monitored at the Garrison powerplant on water discharged through the dam during the period July through December 2008.

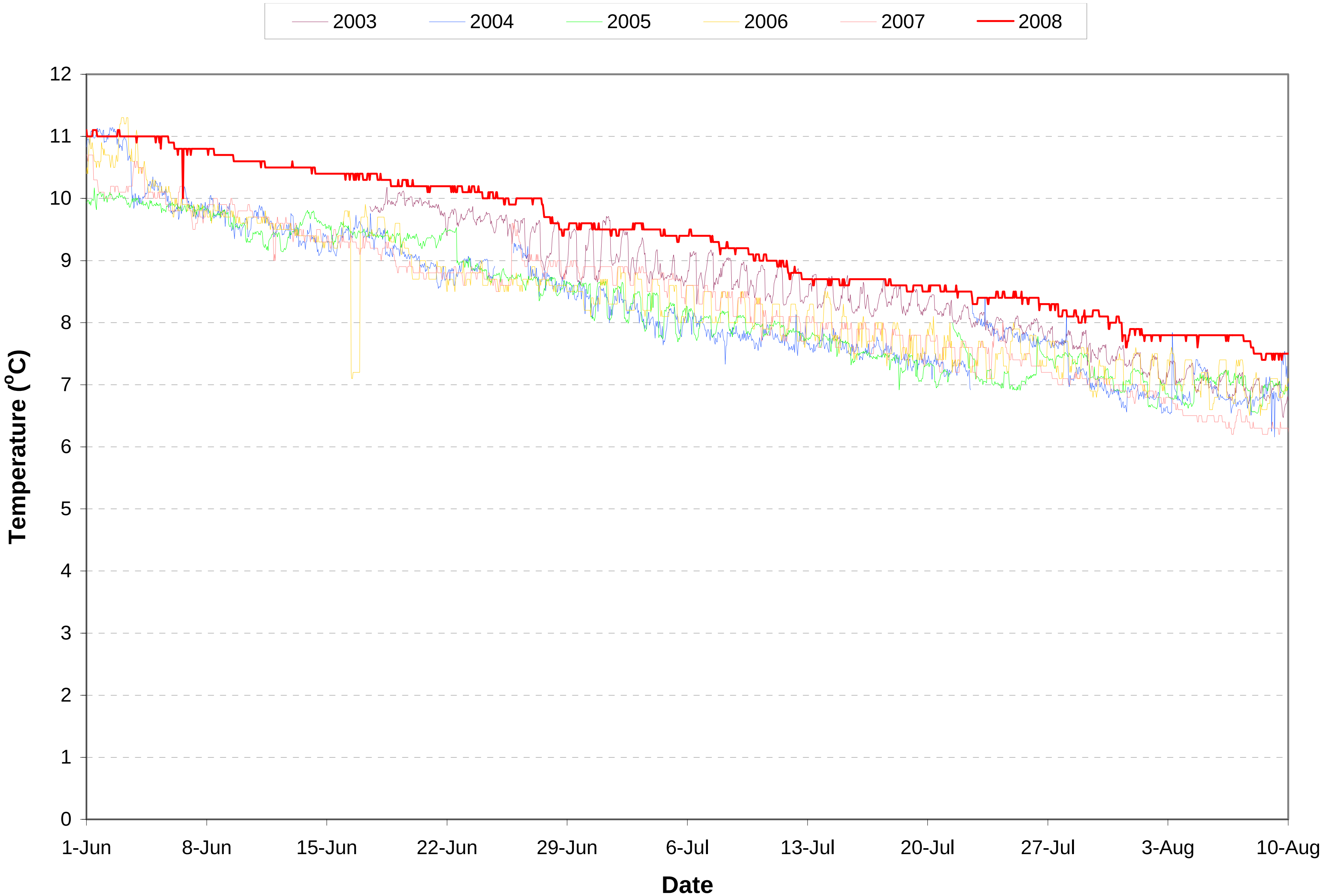


Plate 120. Hourly **d**issolved oxygen concentrations of water discharged through Garrison Dam during the period June through mid-August in 2003, 2004, 2005, 2006, 2007, and 2008.

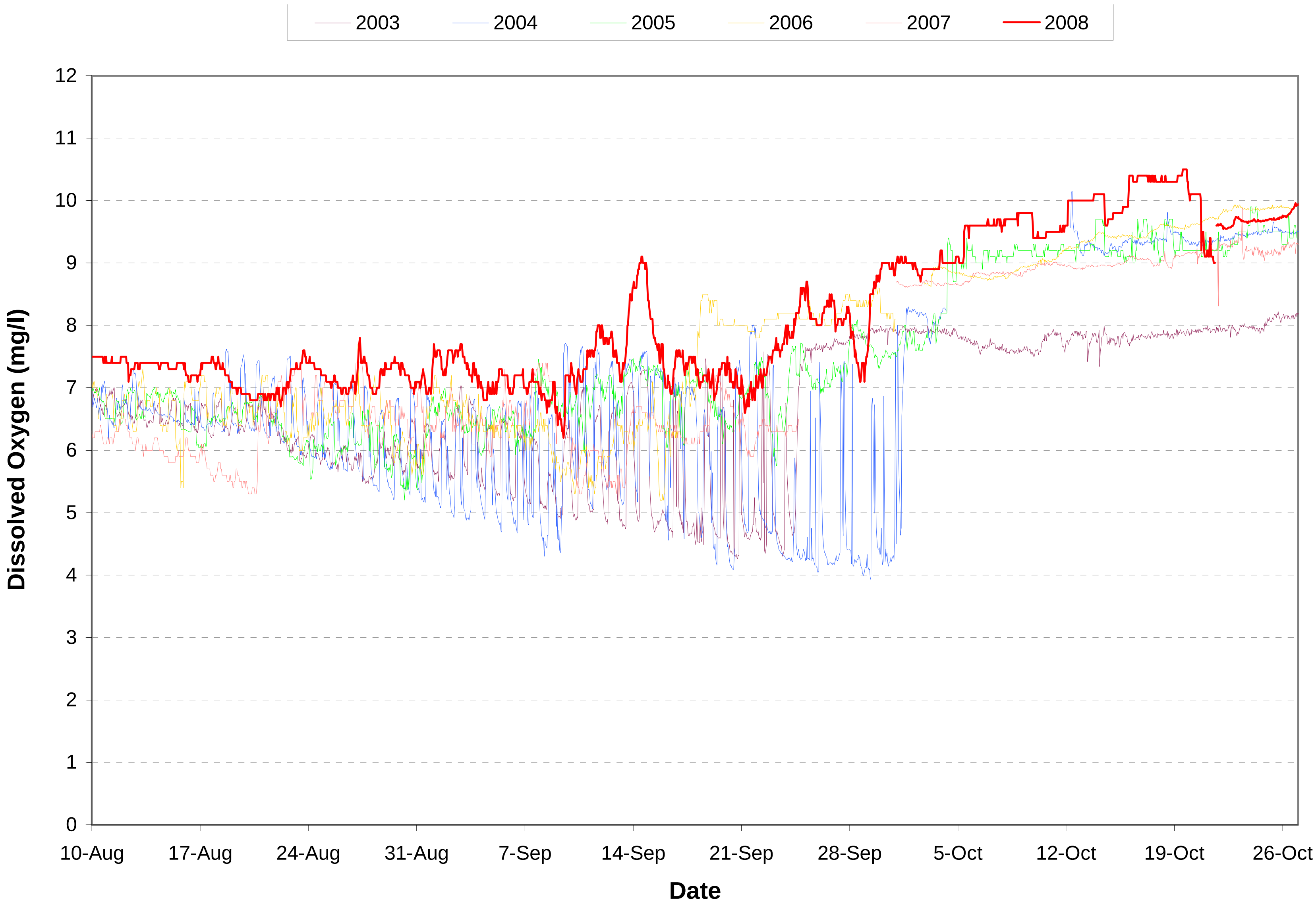


Plate 121. Hourly dissolved oxygen concentrations of water discharged through Garrison Dam during the period mid-August through October in 2003, 2004, 2005, 2006, 2007, and 2008.

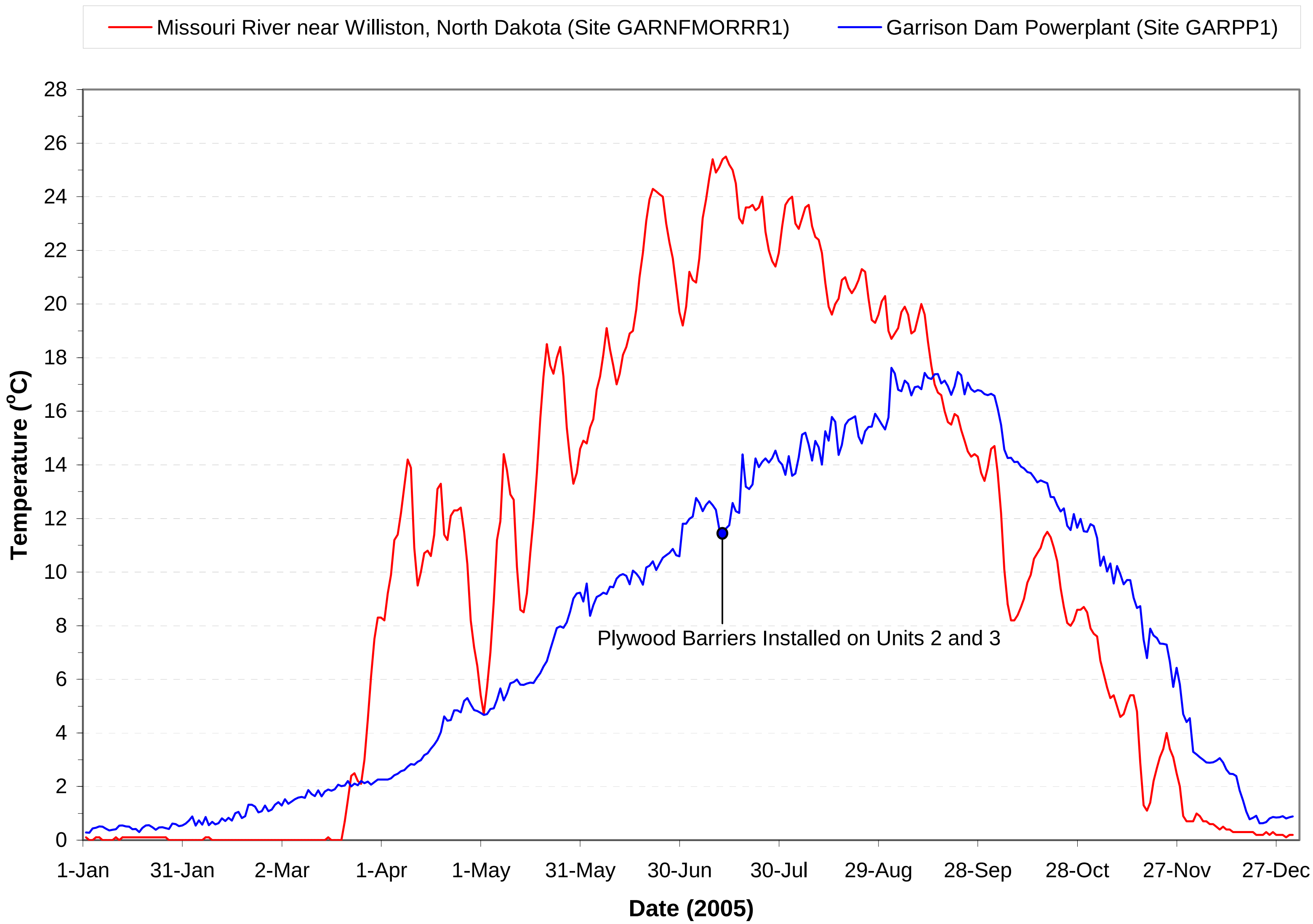


Plate 122. Mean daily water temperatures monitored at the Garrison Powerplant (i.e., site GARPP1) and the Missouri River near Williston, North Dakota (i.e., site GARNFMORRR1) during 2005.

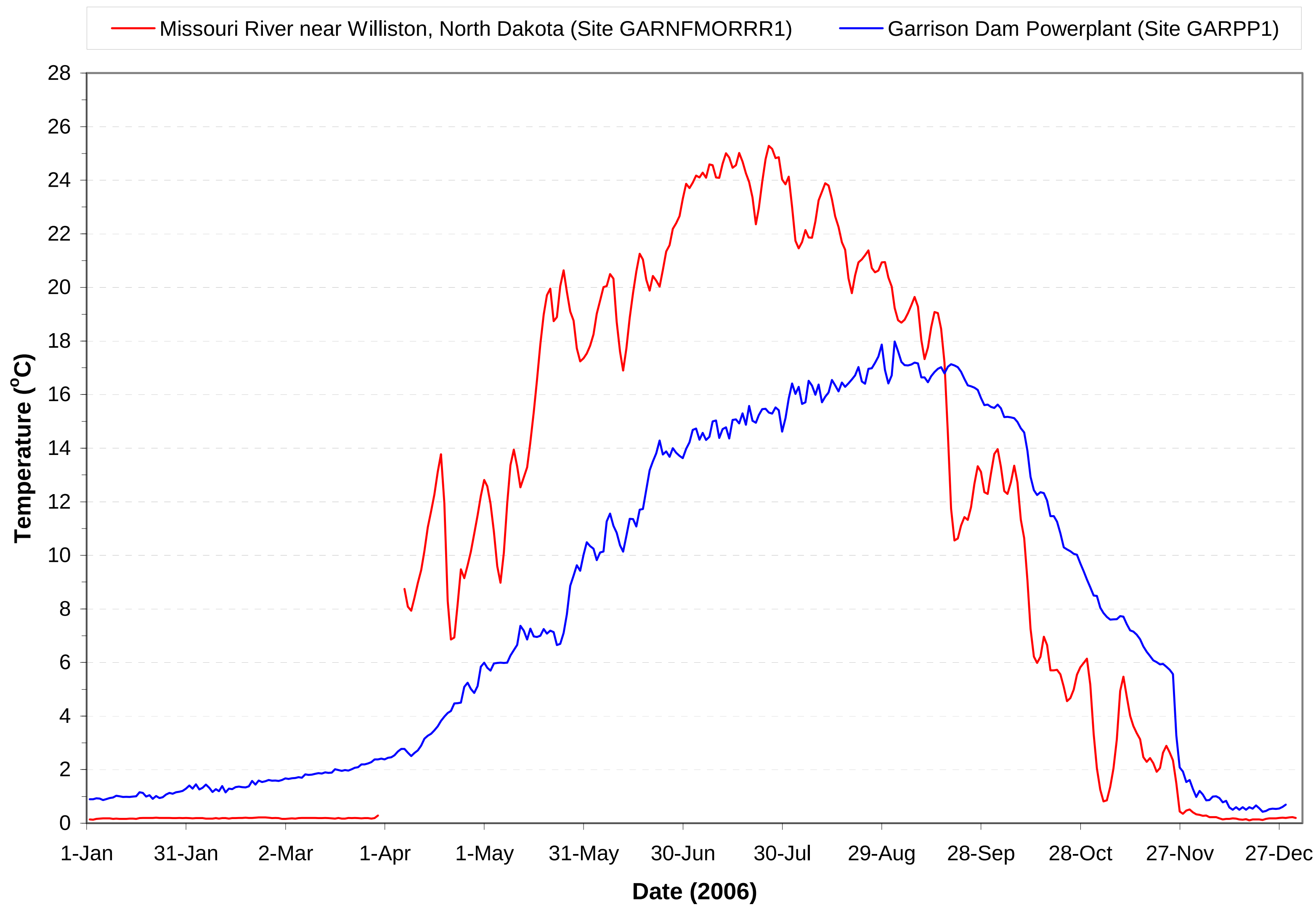


Plate 123. Mean daily water temperatures monitored at the Garrison Powerplant (i.e., site GARPP1) and the Missouri River near Williston, North Dakota (i.e., site GARNFMORRR1) during 2006.

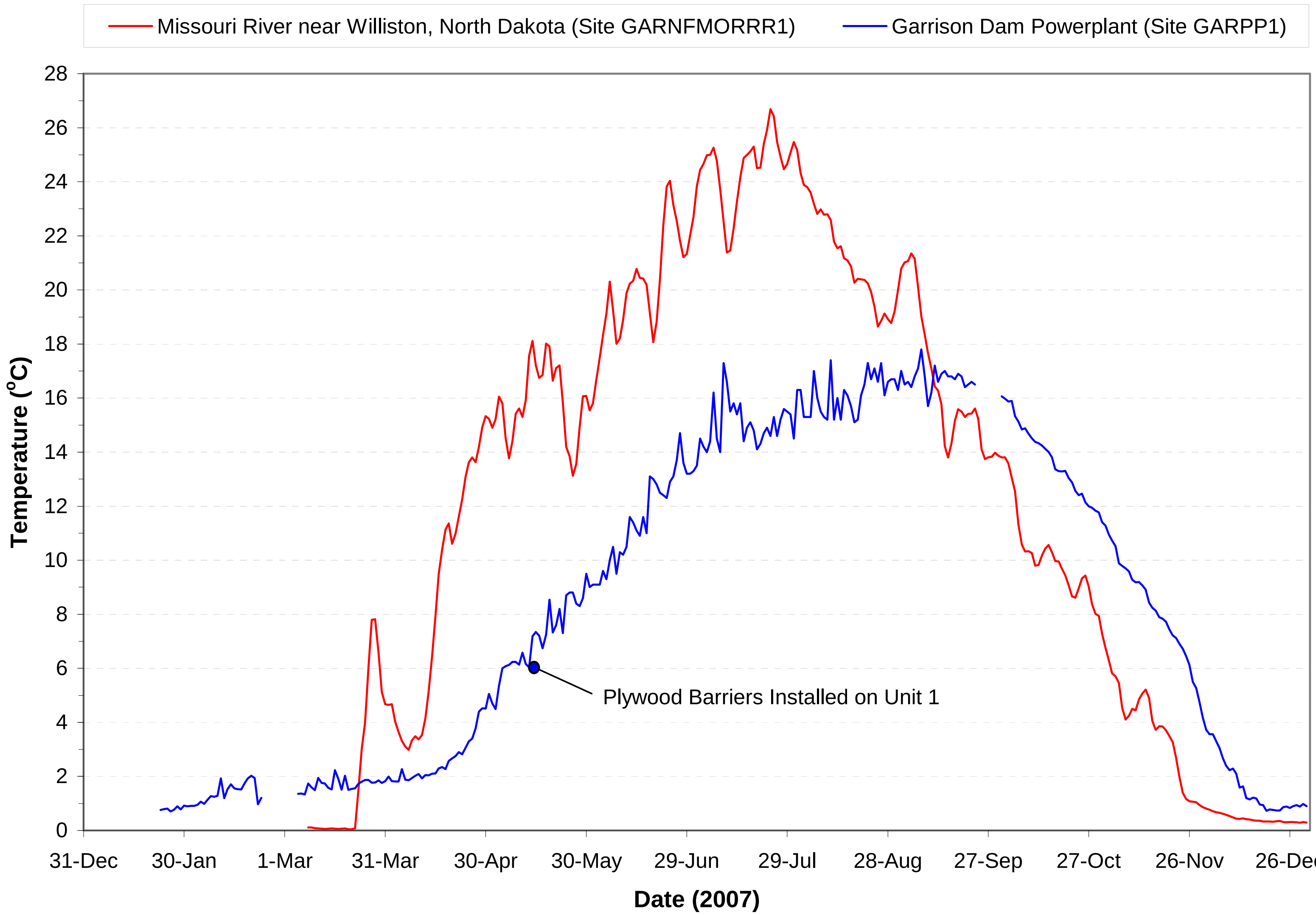


Plate 124. Mean daily water temperatures monitored at the Garrison Powerplant (i.e., site GARPP1) and the Missouri River near Williston, North Dakota (i.e., site GARNFMORRR1) during 2007.

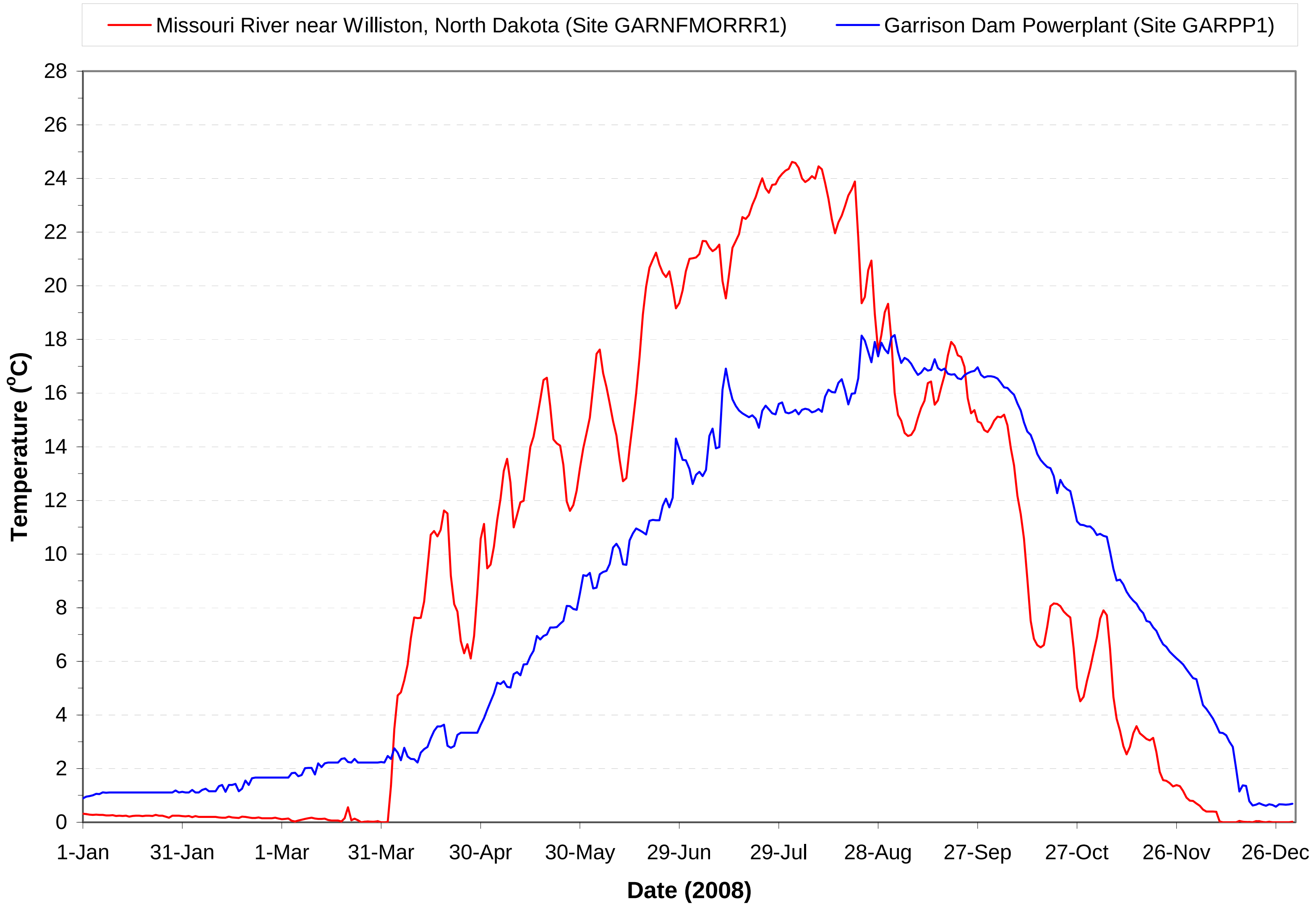


Plate 125. Mean daily water temperatures monitored at the Garrison Powerplant (i.e., site GARPP1) and the Missouri River near Williston, North Dakota (i.e., site GARNFMORRR1) during 2008.

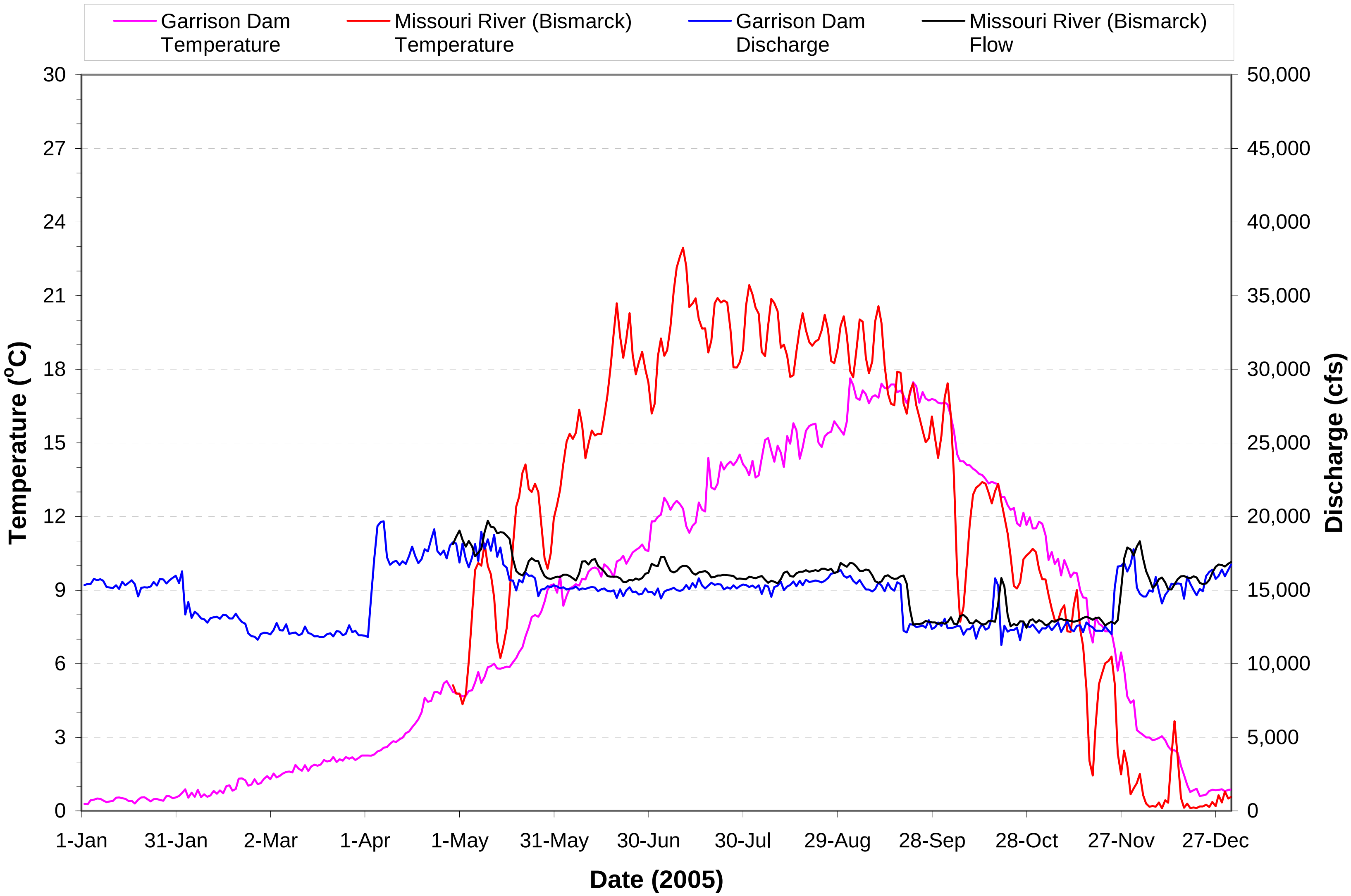


Plate 126. Mean daily water temperature and discharge for the Garrison Dam discharge and Missouri River at Bismarck, North Dakota for 2005. (Daily means based on hourly measurements.)

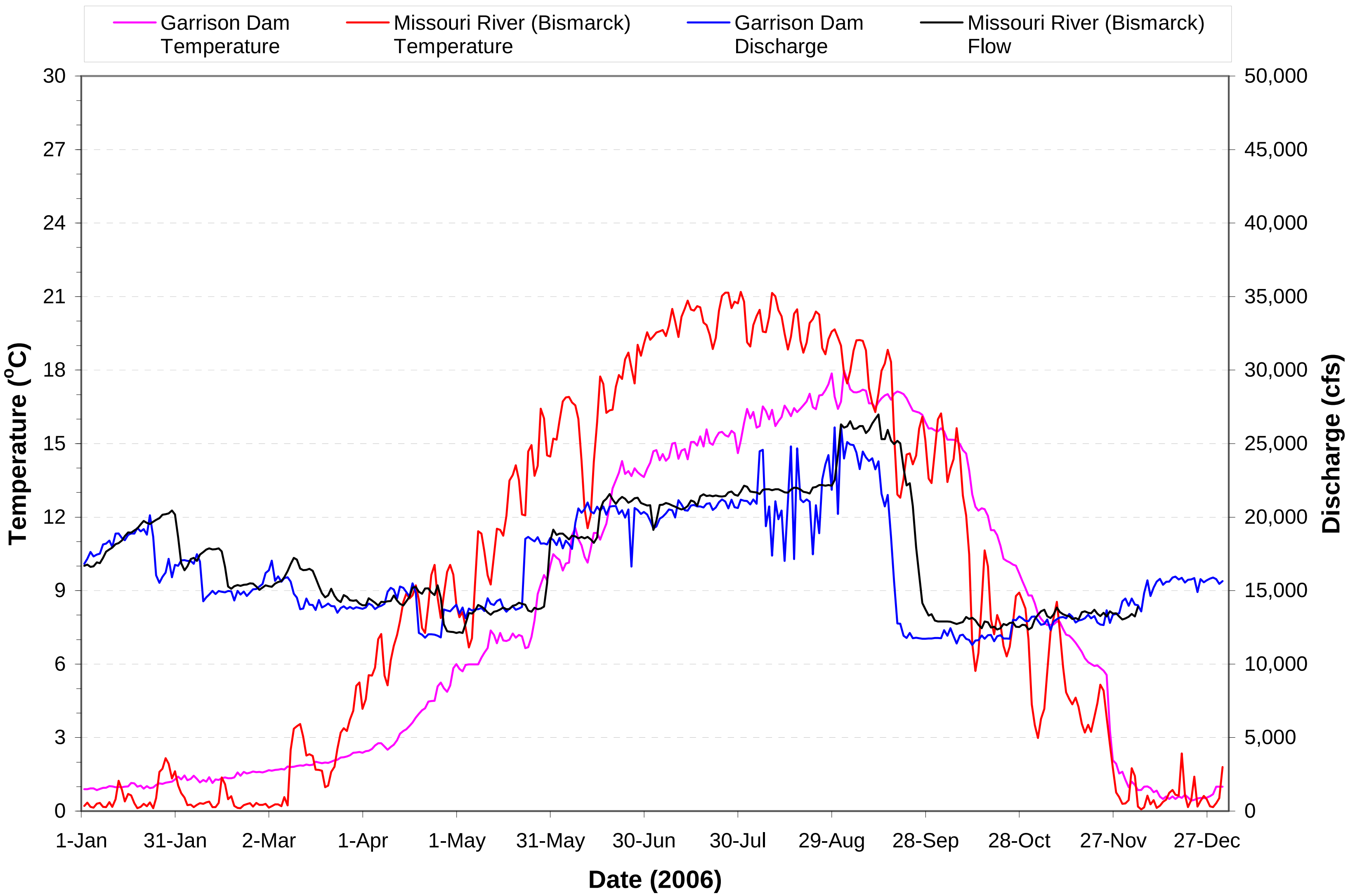


Plate 127. Mean daily water temperature and discharge for the Garrison Dam discharge and Missouri River at Bismarck, North Dakota for 2006. (Daily means based on hourly measurements.)

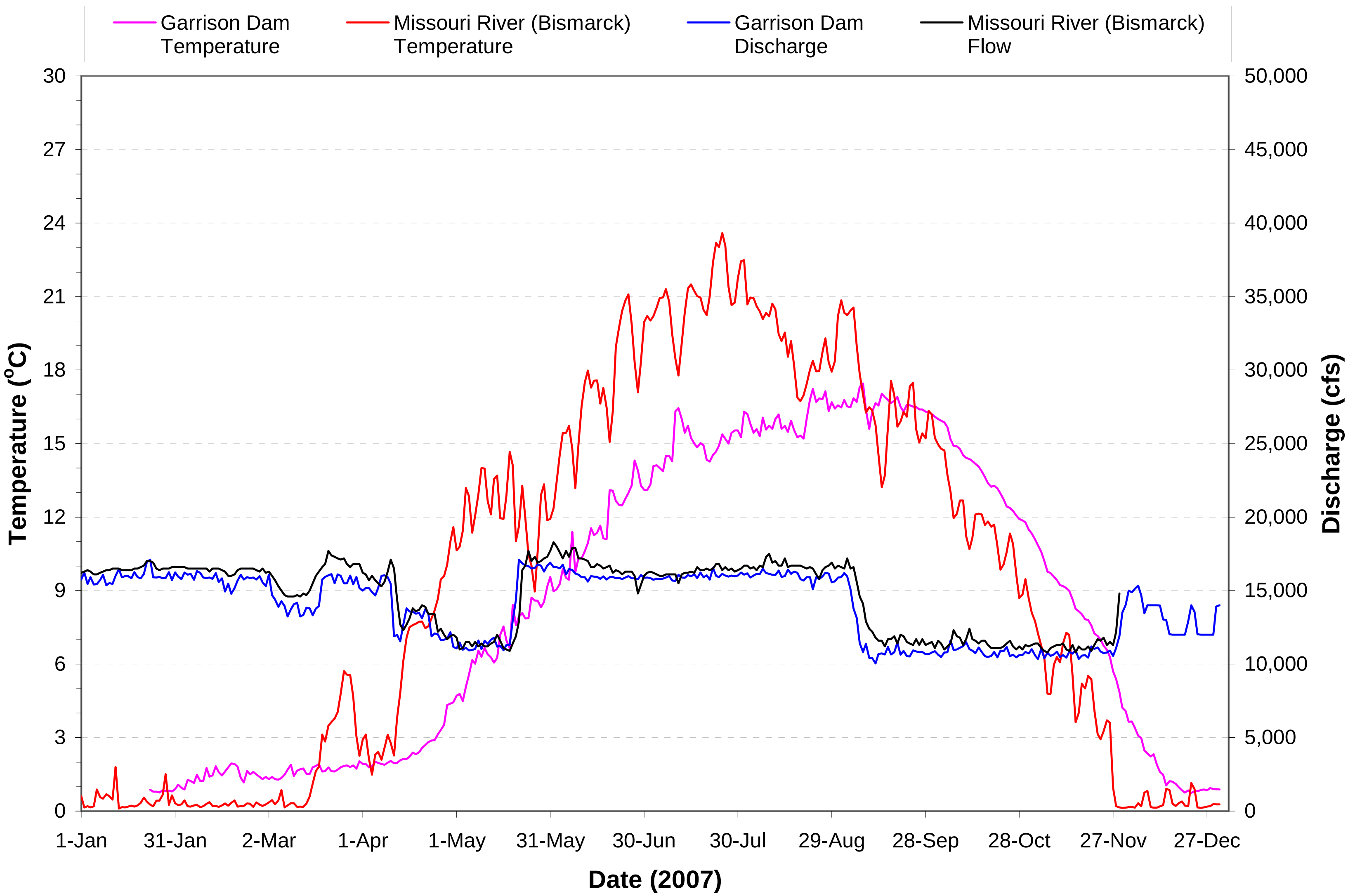


Plate 128. Mean daily water temperature and discharge for the Garrison Dam discharge and Missouri River at Bismarck, North Dakota for 2007. (Daily means based on hourly measurements.)

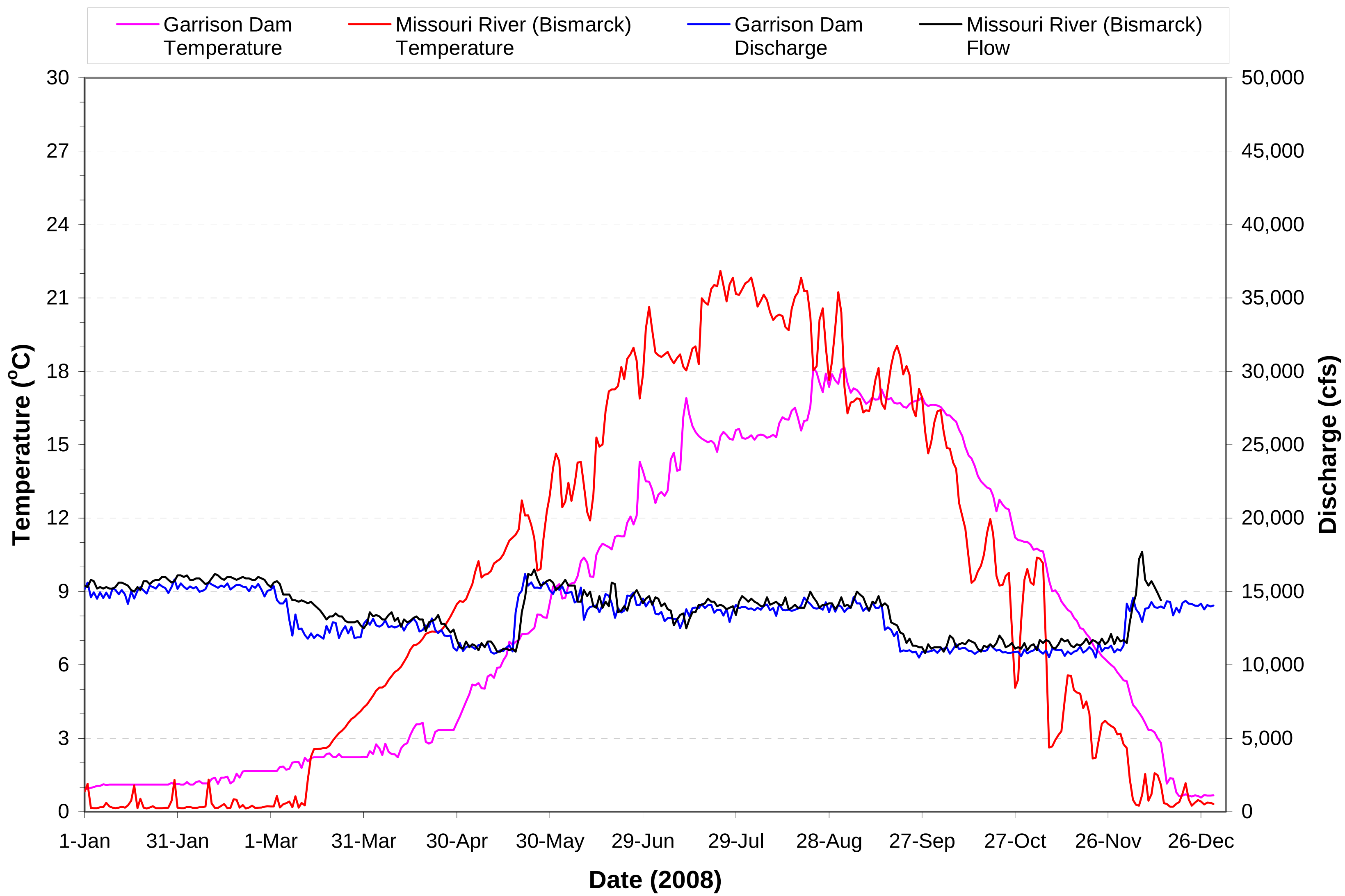


Plate 129. Mean daily water temperature and discharge for the Garrison Dam discharge and Missouri River at Bismarck, North Dakota for 2008. (Daily means based on hourly measurements.)

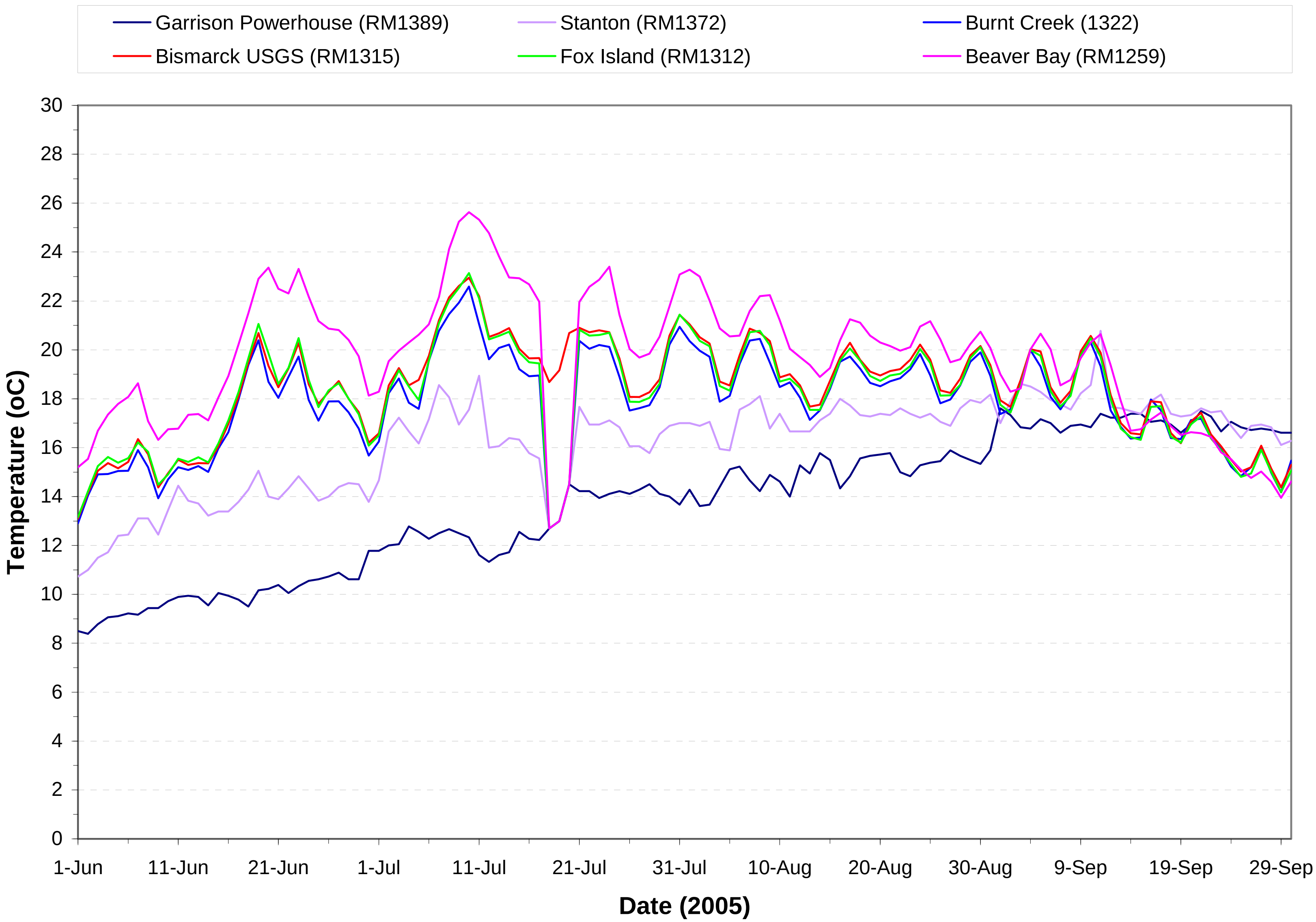


Plate 130. Mean daily water temperatures monitored in the Missouri River from Garrison Dam to Beaver Bay for the period June through September 2005.

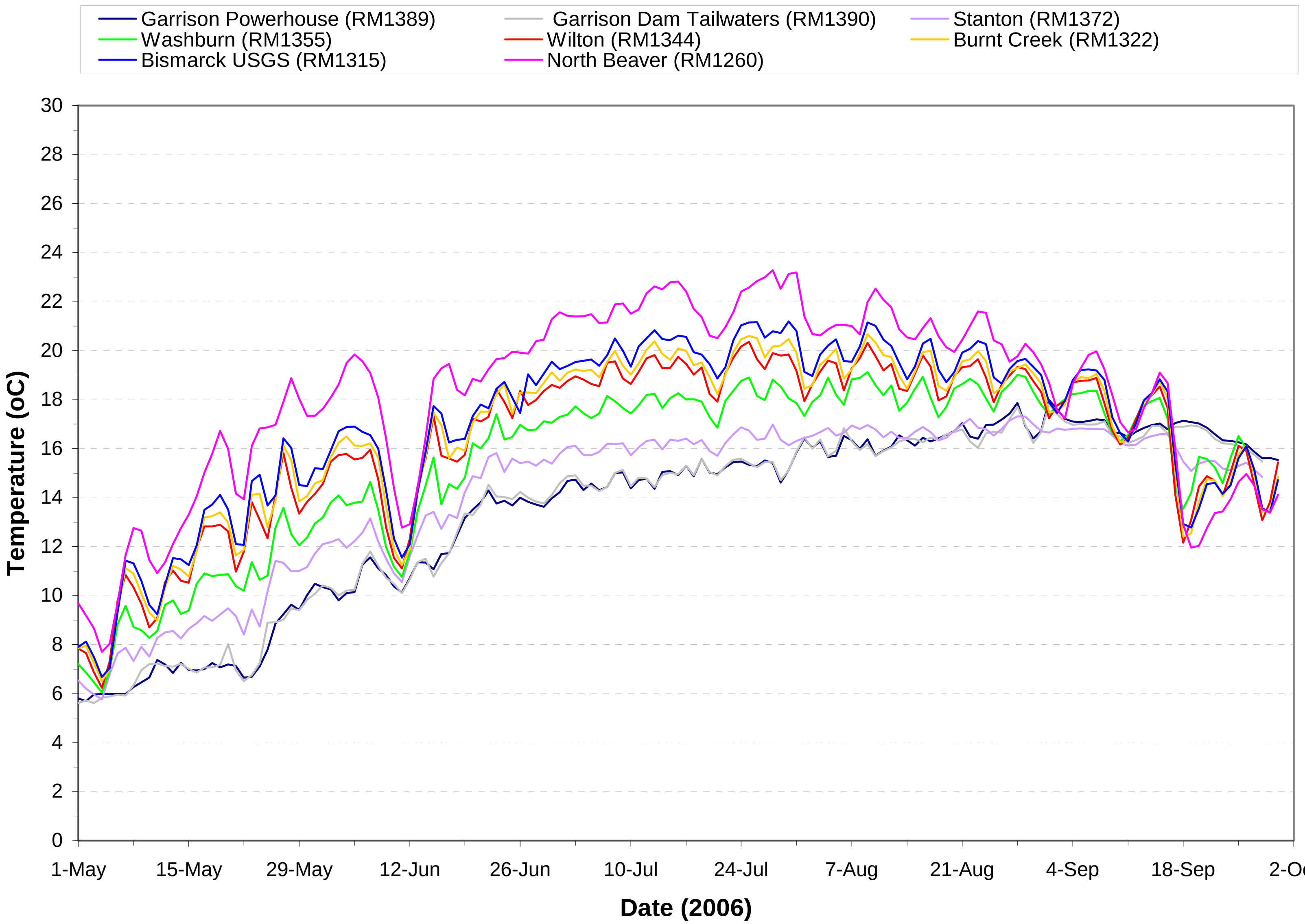


Plate 131. Mean daily water temperatures monitored in the Missouri River from Garrison Dam to Beaver Bay for the period May through September 2006.

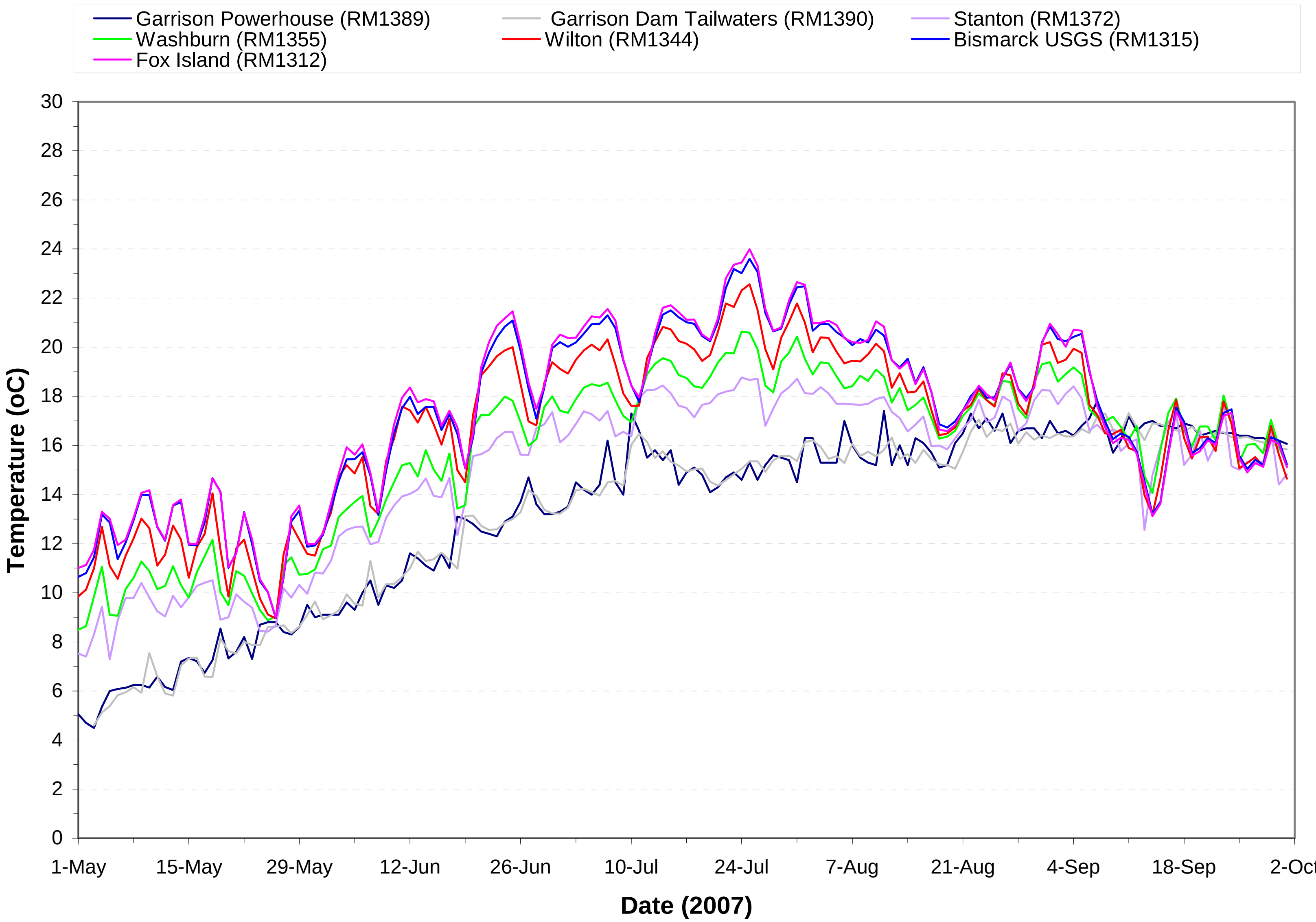


Plate 132. Mean daily water temperatures monitored in the Missouri River from Garrison Dam to Fox Island for the period May through September 2007.

Plate 133. Summary of monthly (May through September) water quality conditions monitored in Oahe Reservoir near Oahe Dam (Site OAHLK1073A) during the 5-year period 2004 through 2008.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	25	1579.5	1577.6	1570.9	1594.0	-----	-----	-----
Water Temperature (C)	0.1	1,100	13.2	11.8	5.7	24.9	18.3[1,5]	226	21%
Hypolimnion Water Temperature (C)[E]	0.1	338	10.2	10.2	6.1	14.6	18.3[1,5]	0	0%
Dissolved Oxygen (mg/l)	0.1	1,100	9.0	8.7	6.0	12.2	6[1,6,8], 7[1,6,8]	0, 79	0%, 7%
Dissolved Oxygen (% Sat.)	0.1	1,100	88.9	92.3	56.5	108.7	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	762	9.2	8.8	6.3	12.2	5[3,6]	0	0%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	338	8.6	8.5	6.0	11.4	6[1,6,8]	0	0%
Specific Conductance (umho/cm)	1	1,099	671	689	534	765	-----	-----	-----
pH (S.U.)	0.1	968	8.3	8.3	7.4	8.8	6.5[1,2,6], 9.0[1,2,5], 9.5[4,5]	0	0%
Turbidity (NTUs)	1	1,099	5	2	n.d.	48	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	1,058	361	364	256	473	-----	-----	-----
Secchi Depth (in.)	1	25	150	144	70	252	-----	-----	-----
Alkalinity, Total (mg/l)	7	51	171	170	140	208	-----	-----	-----
Ammonia, Total (mg/l)	0.02	51	-----	0.03	n.d.	0.40	3.1 [1,5,9], 1.4 [1,7,9]	0	0%
Carbon, Total Organic (mg/l)	0.05	49	3.1	3.1	1.6	4.7	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	30	9	8	n.d.	20	-----	-----	-----
Chloride (mg/l)	1	31	10	10	9	11	175[1,5], 100[1,7], 438[2,5], 250[2,7]	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	1,049	-----	1	n.d.	7	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	23	-----	1	n.d.	11	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	37	460	460	410	510	1,750[2,5], 1,000[2,7], 3,500[4,5], 2,000[4,7]	0	0%
Iron, Total (ug/l)	40	25	93	80	n.d.	262	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	51	0.4	0.3	n.d.	1.3	-----	-----	-----
Manganese, Total (ug/l)	2	25	25	15	n.d.	80	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	51	-----	n.d.	n.d.	0 19	10[2,5]	0	0%
Phosphorus, Dissolved (mg/l)	0.02	39	-----	0.02	n.d.	0.08	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	51	0.05	0.04	n.d.	0 20	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	49	-----	n.d.	n.d.	0.05	-----	-----	-----
Sulfate (mg/l)	1	37	197	200	163	220	875[2,5], 500[2,7]	0	0%
Suspended Solids, Total (mg/l)	4	51	-----	n.d.	n.d.	9	53[1,5], 30[1,7]	0	0%
Microcystin, Total (ug/l)	0.2	19	-----	n.d.	n.d.	n.d.	-----	-----	-----
Coldwater Permanent Fish Life Propagation Habitat[F]	-----	25	-----	-----	-----	-----	D.O ≥ 6 mg/l W.Temp. ≤ 18 3 C	0	0%

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for the protection of coldwater permanent fish life propagation waters.
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of immersion and limited contact recreation waters (applies only to epilimnion and metalimnion if water body stratified).
- (4) Criteria for the protection of commerce and industry waters.
- (5) Daily maximum criterion (monitoring results directly comparable to criterion).
- (6) Daily minimum criterion (monitoring results directly comparable to criterion).
- (7) 30-day average criterion (monitoring results not directly comparable to criterion).
- (8) The 7.0 mg/l criterion applies to spawning areas during spawning season, and the 6.0 mg/l criterion applies otherwise.
- (9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5 C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1 C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5 C occurs over a 1-meter depth increment.

(F) Evaluates the occurrence of Coldwater Permanent Fish Life Propagation habitat (i e., at least a 1-meter layer of water with a temperature ≤ 18.3 C and dissolved oxygen ≥ 6 mg/l). The "No. of Obs." is the number of monthly water column depth-profiles measured. The "No. of WQS Exceedences" is the number of occurrences where no Coldwater Permanent Fish Life Propagation habitat was present anywhere within the measured water column depth-profile.

Plate 134. Summary of monthly (June through September) water quality conditions monitored in Oahe Reservoir near Cow Creek (site OAHLK1090DW) during the 3-year period 2005 through 2007.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	12	1577.1	1576.8	1570.9	1583 2	-----	-----	-----
Water Temperature (C)	0.1	486	15.6	15.4	8.1	27 1	18.3[1,5]	150	31%
Hypolimnion Water Temperature (C)[E]	0.1	169	10.3	10.3	8.1	13 9	18.3[1,5]	0	0%
Dissolved Oxygen (mg/l)	0.1	486	8.1	8.1	6.1	10.3	6[1,6,8], 7[1,6,8]	0, 78	0%, 16%
Dissolved Oxygen (% Sat.)	0.1	486	84.9	86.8	59.2	102.8	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	317	8.1	8.1	6.2	10.0	5[3,6]	0	0%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	169	8.1	8.3	6.1	10 3	6[1,6,8]	0	0%
Specific Conductance (umho/cm)	1	486	676	694	536	770	-----	-----	-----
pH (S.U.)	0.1	486	8.3	8.4	7.5	8 9	6.5[1,2,6], 9.0[1,2,5], 9.5[4,5]	0	0%
Turbidity (NTUs)	1	484	5.8	2.1	n.d.	79.9	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	486	359	553	274	468	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	486	-----	1	n.d.	39	-----	-----	-----
Secchi Depth (in)	1	12	139	137	60	228	-----	-----	-----
Coldwater Permanent Fish Life Propagation Habitat[F]	-----	12	-----	-----	-----	-----	D.O ≥ 6 mg/l W.Temp. ≤ 18 3 C	0	0%

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.
- (1) Criteria for the protection of coldwater permanent fish life propagation waters.
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of immersion and limited contact recreation waters (applies only to epilimnion and metalimnion if water body stratified).
- (4) Criteria for the protection of commerce and industry waters.
- (5) Daily maximum criterion (monitoring results directly comparable to criterion).
- (6) Daily minimum criterion (monitoring results directly comparable to criterion).
- (7) 30-day average criterion (monitoring results not directly comparable to criterion).
- (8) The 7.0 mg/l criterion applies to spawning areas during spawning season, and the 6.0 mg/l criterion applies otherwise.
- (9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5 C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1 C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5 C occurs over a 1-meter depth increment.

(F) Evaluates the occurrence of Coldwater Permanent Fish Life Propagation habitat (i e., at least a 1-meter layer of water with a temperature ≤ 18.3 C and dissolved oxygen ≥ 6 mg/l). The "No. of Obs." is the number of monthly water column depth-profiles measured. The "No. of WQS Exceedences" is the number of occurrences where no Coldwater Permanent Fish Life Propagation habitat was present anywhere within the measured water column depth-profile.

Plate 135. Summary of monthly (May through September) water quality conditions monitored in Oahe Reservoir near the confluence of the Cheyenne River (Site OAHLK1110DW) during the 4-year period 2005 through 2008.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	**No. of Obs.**	**Mean[C]**	**Median**	**Min.**	**Max.**	**State WQS Criteria[D]**	**No. of WQS Exceedences**	**Percent WQS Exceedence**
Pool Elevation (ft-msl)	0.1	17	1581.0	1580.2	1570.9	1593.8	-----	-----	-----
Water Temperature (C)	0.1	549	16.8	16.9	7.4	25.5	18.3[1,5]	220	40%
Hypolimnion Water Temperature (C)[E]	0.1	138	15.5	12.7	9.7	15.4	18.3[1,5]	0	0%
Dissolved Oxygen (mg/l)	0.1	549	8.1	8.1	3.4	11.4	6[1,6,8], 7[1,6,8]	42, 102	8%, 19%
Dissolved Oxygen (% Sat.)	0.1	549	86.8	91.6	33.9	113.3	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	411	8.4	8.3	5.5	11.4	5[3,6]	0	0%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	138	7.4	7.1	3.4	11.4	6[1,6,8]	29	21%
Specific Conductance (umho/cm)	1	549	682	690	536	782	-----	-----	-----
pH (S.U.)	0.1	515	8.3	8.4	7.5	8.8	6 5[1,2,6], 9.0[1,2,5], 9 5[4,5]	0	0%
Turbidity (NTUs)	1	544	5	3	n.d.	37	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	549	350	332	245	459	-----	-----	-----
Secchi Depth (in.)	1	17	114	120	56	192	-----	-----	-----
Alkalinity, Total (mg/l)	7	37	163	161	140	180	-----	-----	-----
Ammonia, Total (mg/l)	0.02	37	-----	n.d.	n.d.	0.27	2.6 [1,5,9], 1.0 [1,7,9]	0	0%
Carbon, Total Organic (mg/l)	0.05	35	3.1	3.1	1.3	4.6	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	26	12	11	2	19	-----	-----	-----
Chloride (mg/l)	1	26	10	10	8	12	175[1,5], 100[1,7], 438[2,5], 250[2,7]	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	509	1	1	n.d.	6	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	17	-----	2	n.d.	12	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	36	461	456	414	556	1,750[2,5], 1,000[2,7], 3,500[4,5], 2,000[4,7]	0	0%
Iron, Total (ug/l)	40	25	163	130	n.d.	480	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.2	37	0.4	0.3	n.d.	2.5	-----	-----	-----
Manganese, Total (ug/l)	2	25	32	19	n.d.	129	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	36	-----	n.d.	n.d.	0.20	10[2,5]	0	0%
Phosphorus, Dissolved (mg/l)	0.02	37	-----	0.02	n.d.	0.08	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	37	0.05	0.04	n.d.	0.25	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	37	-----	n.d.	n.d.	0.04	-----	-----	-----
Sulfate (mg/l)	1	35	194	200	148	231	875[2,5], 500[2,7]	0	0%
Suspended Solids, Total (mg/l)	4	36	-----	n.d.	n.d.	13	53[1,5], 30[1,7]	0	0%
Microcystin, Total (ug/l)	0.2	17	-----	n.d.	n.d.	0.2	-----	-----	-----
Coldwater Permanent Fish Life Propagation Habitat[F]	-----	17	-----	-----	-----	-----	D.O ≥ 6 mg/l W.Temp. ≤ 18.3 C	2	12%

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.
- (1) Criteria for the protection of coldwater permanent fish life propagation waters.
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of immersion and limited contact recreation waters (applies only to epilimnion and metalimnion if water body stratified).
- (4) Criteria for the protection of commerce and industry waters.
- (5) Daily maximum criterion (monitoring results directly comparable to criterion).
- (6) Daily minimum criterion (monitoring results directly comparable to criterion).
- (7) 30-day average criterion (monitoring results not directly comparable to criterion).
- (8) The 7.0 mg/l criterion applies to spawning areas during spawning season, and the 6.0 mg/l criterion applies otherwise.
- (9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5 C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1 C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5 C occurs over a 1-meter depth increment.

(F) Evaluates the occurrence of Coldwater Permanent Fish Life Propagation habitat (i e., at least a 1-meter layer of water with a temperature ≤ 18.3 C and dissolved oxygen ≥ 6 mg/l). The "No. of Obs." is the number of monthly water column depth-profiles measured. The "No. of WQS Exceedences" is the number of occurrences where no Coldwater Permanent Fish Life Propagation habitat was present anywhere within the measured water column depth-profile.

Plate 136. Summary of monthly (June through September) water quality conditions monitored in Oahe Reservoir near Sutton Bay (site OAHLK1135DW) during the 3-year period 2005 through 2007.

Parameter	Monitoring Results[(A)]						Water Quality Standards Attainment		
	Detection Limit[(B)]	No. of Obs.	Mean[(C)]	Median	Min.	Max.	State WQS Criteria[(D)]	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	11	1577.1	1576.9	1570.9	1583.2	-----	-----	-----
Water Temperature (C)	0 1	317	18.7	18.6	10.5	25.4	18.3[(1,5)]	163	51%
Hypolimnion Water Temperature (C)[(E)]	0.1	55	14.7	14.7	12.6	17.8	18.3[(1,5)]	0	0%
Dissolved Oxygen (mg/l)	0.1	317	7.4	7.8	3.5	9.7	6[(1,6,8)], 7[(1,6,8)]	50, 82	16%, 26%
Dissolved Oxygen (% Sat.)	0.1	316	83.1	88.5	35.9	107.3	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[(E)]	0.1	256	7.9	7.9	5.2	9.7	5[(3,6)]	0	0%
Hypolimnion Dissolved Oxygen (mg/l)[(E)]	0.1	61	5.4	4.8	3.5	8.0	6[(1,6,8)]	42	69%
Specific Conductance (umho/cm)	1	317	654	659	532	732	-----	-----	-----
pH (S.U.)	0.1	317	8.3	8.3	7.6	8.6	6.5[(1,2,6)], 9.0[(1,2,5)], 9.5[(4,5)]	0	0%
Turbidity (NTUs)	1	315	6.2	3.7	0.6	34.1	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	316	378	376	296	469	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	313	-----	1	n.d.	6	-----	-----	-----
Secchi Depth (in)	1	11	90	100	40	122	-----	-----	-----
Coldwater Permanent Fish Life Propagation Habitat[(F)]	-----	11	-----	-----	-----	-----	D.O ≥ 6 mg/l W.Temp. ≤ 18.3 C	5	45%

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.
- (1) Criteria for the protection of coldwater permanent fish life propagation waters.
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of immersion and limited contact recreation waters (applies only to epilimnion and metalimnion if water body stratified).
- (4) Criteria for the protection of commerce and industry waters.
- (5) Daily maximum criterion (monitoring results directly comparable to criterion).
- (6) Daily minimum criterion (monitoring results directly comparable to criterion).
- (7) 30-day average criterion (monitoring results not directly comparable to criterion).
- (8) The 7.0 mg/l criterion applies to spawning areas during spawning season, and the 6.0 mg/l criterion applies otherwise.
- (9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5 C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1 C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5 C occurs over a 1-meter depth increment.

(F) Evaluates the occurrence of Coldwater Permanent Fish Life Propagation habitat (i e., at least a 1-meter layer of water with a temperature ≤ 18.3 C and dissolved oxygen ≥ 6 mg/l). The "No. of Obs." is the number of monthly water column depth-profiles measured. The "No. of WQS Exceedences" is the number of occurrences where no Coldwater Permanent Fish Life Propagation habitat was present anywhere within the measured water column depth-profile.

Plate 137. Summary of monthly (June through September) water quality conditions monitored in Oahe Reservoir near Whitlocks Bay (Site OAHLK1153DW) during the 4-year period 2005 through 2008.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	17	1581.0	1580.2	1571.1	1593.7	-----	-----	-----
Water Temperature (C)	0.1	438	18.2	18.5	7.6	25.7	18.3[1,5]	238	54%
Hypolimnion Water Temperature (C)[E]	0.1	83	15.5	15.1	11.5	19.9	18.3[1,5]	11	13%
Dissolved Oxygen (mg/l)	0.1	438	7.7	7.8	2.5	11.3	6[1,6,8], 7[1,6,8]	60, 86	14%, 20%
Dissolved Oxygen (% Sat.)	0.1	438	84.6	89.3	27.7	104.8	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	355	8.1	7.9	4.1	11.3	5[3,6]	3	1%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	83	5.9	5.8	2.5	8.3	6[1,6,8]	43	52%
Specific Conductance (umho/cm)	1	437	645	651	539	741	-----	-----	-----
pH (S.U.)	0.1	438	8.3	8.4	7.5	8.7	6.5[1,2,6], 9.0[1,2,5], 9.5[4,5]	0	0%
Turbidity (NTUs)	1	437	4	3	n.d.	24	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	438	373	365	259	492	-----	-----	-----
Secchi Depth (in.)	1	17	83	72	41	156	-----	-----	-----
Alkalinity, Total (mg/l)	7	36	162	160	140	180	-----	-----	-----
Ammonia, Total (mg/l)	0.02	36	-----	0.03	n.d.	0.31	2.6 [1,5,9], 0.94 [1,7,9]	0	0%
Carbon, Total Organic (mg/l)	0.05	34	3.1	3.2	1.6	5.0	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	25	12	11	2	23	-----	-----	-----
Chloride (mg/l)	1	26	9	9	8	10	175[1,5], 100[1,7], 438[2,5], 250[2,7]	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	406	2	1	n.d.	26	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	17	4	5	n.d.	10	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	36	440	430	380	532	1,750[2,5], 1,000[2,7], 3,500[4,5], 2,000[4,7]	0	0%
Iron, Total (ug/l)	40	25	204	170	40	589	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.2						-----	-----	-----
Manganese, Total (ug/l)	2	25	108	70	10	532	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	36	-----	0.02	n.d.	0.30	10[2,5]	0	0%
Phosphorus, Dissolved (mg/l)	0.02	36	-----	0.02	n.d.	0.16	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	36	0.06	0.05	n.d.	0.23	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	36	-----	n.d.	n.d.	0.04	-----	-----	-----
Sulfate (mg/l)	1	34	175	174	144	200	875[2,5], 500[2,7]	0	0%
Suspended Solids, Total (mg/l)	4	36	-----	n.d.	n.d.	14	53[1,5], 30[1,7]	0	0%
Microcystin, Total (ug/l)	0.2	17	-----	n.d.	n.d.	n.d.	-----	-----	-----
Coldwater Permanent Fish Life Propagation Habitat[F]	-----	17	-----	-----	-----	-----	D.O ≥ 6 mg/l W.Temp. ≤ 18.3 C	8	47%

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for the protection of coldwater permanent fish life propagation waters.
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of immersion and limited contact recreation waters (applies only to epilimnion and metalimnion if water body stratified).
- (4) Criteria for the protection of commerce and industry waters.
- (5) Daily maximum criterion (monitoring results directly comparable to criterion).
- (6) Daily minimum criterion (monitoring results directly comparable to criterion).
- (7) 30-day average criterion (monitoring results not directly comparable to criterion).
- (8) The 7.0 mg/l criterion applies to spawning areas during spawning season, and the 6.0 mg/l criterion applies otherwise.
- (9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5 C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1 C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5 C occurs over a 1-meter depth increment.

(F) Evaluates the occurrence of Coldwater Permanent Fish Life Propagation habitat (i e., at least a 1-meter layer of water with a temperature ≤ 18.3 C and dissolved oxygen ≥ 6 mg/l). The "No. of Obs." is the number of monthly water column depth-profiles measured. The "No. of WQS Exceedences" is the number of occurrences where no Coldwater Permanent Fish Life Propagation habitat was present anywhere within the measured water column depth-profile.

Plate 138. Summary of monthly (June through September) water quality conditions monitored in Oahe Reservoir near Swan Creek (site OAHLK1176DW) during the 3-year period 2005 through 2007.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	12	1577 1	1576 9	1571.1	1583 2	-----	-----	-----
Water Temperature (C)	0.1	213	20 9	20.4	15.5	25 3	18 3[1,5]	169	79%
Hypolimnion Water Temperature (C)[E]	0.1	5	19.6	19.4	18.6	21 2	18 3[1,5]	5	100%
Dissolved Oxygen (mg/l)	0.1	213	7.6	7.8	2.7	9.7	6[1,6,8], 7[1,6,8]	15, 34	7%, 16%
Dissolved Oxygen (% Sat.)	0.1	213	88.7	90 2	31.4	110.7	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	208	7.7	7.8	4.5	9.7	5[3,6]	3	1%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	5	4 5	4 9	2.7	5 2	6[1,6,8]	5	100%
Specific Conductance (umho/cm)	1	213	649	659	529	763	-----	-----	-----
pH (S.U.)	0.1	213	8.4	8.4	7.8	8.7	6.5[1,2,6], 9.0[1,2,5], 9.5[4,5]	0, 14	0%, 7%
Turbidity (NTUs)	1	211	6.2	4.7	1.5	26.4	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	213	402	411	294	477	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	212	2	2	n.d.	11	-----	-----	-----
Secchi Depth (in)	1	12	59	55	37	92	-----	-----	-----
Coldwater Permanent Fish Life Propagation Habitat[F]	-----	12	-----	-----	-----	-----	D.O ≥ 6 mg/l W.Temp. ≤ 18.3 C	9	75%

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.
- (1) Criteria for the protection of coldwater permanent fish life propagation waters.
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of immersion and limited contact recreation waters (applies only to epilimnion and metalimnion if water body stratified).
- (4) Criteria for the protection of commerce and industry waters.
- (5) Daily maximum criterion (monitoring results directly comparable to criterion).
- (6) Daily minimum criterion (monitoring results directly comparable to criterion).
- (7) 30-day average criterion (monitoring results not directly comparable to criterion).
- (8) The 7.0 mg/l criterion applies to spawning areas during spawning season, and the 6.0 mg/l criterion applies otherwise.
- (9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5 C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1 C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5 C occurs over a 1-meter depth increment.

(F) Evaluates the occurrence of Coldwater Permanent Fish Life Propagation habitat (i.e , at least a 1-meter layer of water with a temperature ≤ 18.3 C and dissolved oxygen ≥ 6 mg/l). The "No. of Obs." is the number of monthly water column depth-profiles measured. The "No. of WQS Exceedences" is the number of occurrences where no Coldwater Permanent Fish Life Propagation habitat was present anywhere within the measured water column depth-profile.

Plate 139. Summary of monthly (June through September) water quality conditions monitored in Oahe Reservoir near Mobridge, South Dakota (Site OAHLK1196DW) during the 4-year period 2005 through 2008.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	17	1581.1	1580.2	1571.1	1593.7	-----	-----	-----
Water Temperature (C)	0.1	240	20.1	20.0	9.7	26.4	18.3[1,5]	185	77%
Hypolimnion Water Temperature (C)[E]	0.1	0[G]	-----	-----	-----	-----	18.3[1,5]	-----	-----
Dissolved Oxygen (mg/l)	0.1	240	8.0	7.9	5.1	10.8	6[1,6,8], 7[1,6,8]	5, 32	2%, 13%
Dissolved Oxygen (% Sat.)	0.1	240	91.4	91.5	63.7		-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	240	8.0	7.9	5.1	10.8	5[3,6]	0	0%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	-----[G]	-----[G]	-----[G]	-----[G]	-----[G]	6[1,6,8]	-----	-----
Specific Conductance (umho/cm)	1	240	654	657	530	749	-----	-----	-----
pH (S.U.)	0.1	240	8.4	8.4	7.9	8.7	6.5[1,2,6], 9.0[1,2,5], 9.5[4,5]	0	0%
Turbidity (NTUs)	1	238	11	9	1	32	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	240	387	382	262	519	-----	-----	-----
Secchi Depth (in.)	1	17	40	34	17	96	-----	-----	-----
Alkalinity, Total (mg/l)	7	29	162	165	98	180	-----	-----	-----
Ammonia, Total (mg/l)	0.02	29	-----	0.04	n.d.	0.33	2.6 [1,5,9], 0.86 [1,7,9]	0	0%
Carbon, Total Organic (mg/l)	0.05	26	3.2	3.2	2.6	4.4	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	21	13	12	9	22	-----	-----	-----
Chloride (mg/l)	1	21	9	9	8	11	175[1,5], 100[1,7], 438[2,5], 250[2,7]	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	222	4	3	1	17	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	16	6	6	1	15	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	29	454	440	410	560	1,750[2,5], 1,000[2,7], 3,500[4,5], 2,000[4,7]	0	0%
Iron, Total (ug/l)	40	20	344	330	100	699	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.2	29	0.5	0.5	n.d.	2.5	-----	-----	-----
Manganese, Total (ug/l)	2	20	49	47	20	110	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	29	-----	n.d.	n.d.	0.11	10[2,5]	0	0%
Phosphorus, Dissolved (mg/l)	0.02	29	-----	0.02	n.d.	0.09	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	29	0.05	0.05	n.d.	0.15	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	29	-----	n.d.	n.d.	0.04	-----	-----	-----
Sulfate (mg/l)	1	27	174	180	142	200	875[2,5], 500[2,7]	0	0%
Suspended Solids, Total (mg/l)	4	29	-----	8	n.d.	18	53[1,5], 30[1,7]	0	0%
Microcystin, Total (ug/l)	0.2	17	-----	n.d.	n.d.	0.2	-----	-----	-----
Coldwater Permanent Fish Life Propagation Habitat[F]	-----	17	-----	-----	-----	-----	D.O ≥ 6 mg/l W.Temp. ≤ 18.3 C	13	76%

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.
- (1) Criteria for the protection of coldwater permanent fish life propagation waters.
- (2) Criteria for the protection of domestic water supply waters.
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- (6) Daily minimum criterion (monitoring results directly comparable to criterion).
- (7) 30-day average criterion (monitoring results not directly comparable to criterion).
- (8) The 7.0 mg/l criterion applies to spawning areas during spawning season, and the 6.0 mg/l criterion applies otherwise.
- (9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5 C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1 C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5 C occurs over a 1-meter depth increment.

(F) Evaluates the occurrence of Coldwater Permanent Fish Life Propagation habitat (i e., at least a 1-meter layer of water with a temperature ≤ 18.3 C and dissolved oxygen ≥ 6 mg/l). The "No. of Obs." is the number of monthly water column depth-profiles measured. The "No. of WQS Exceedences" is the number of occurrences where no Coldwater Permanent Fish Life Propagation habitat was present anywhere within the measured water column depth-profile.

(G) Depth-profiles did not indicate the presence of a hypolimnion during monitored period. It is assumed that the water column experienced complete mixing due to shallower water depths during the monitored period.

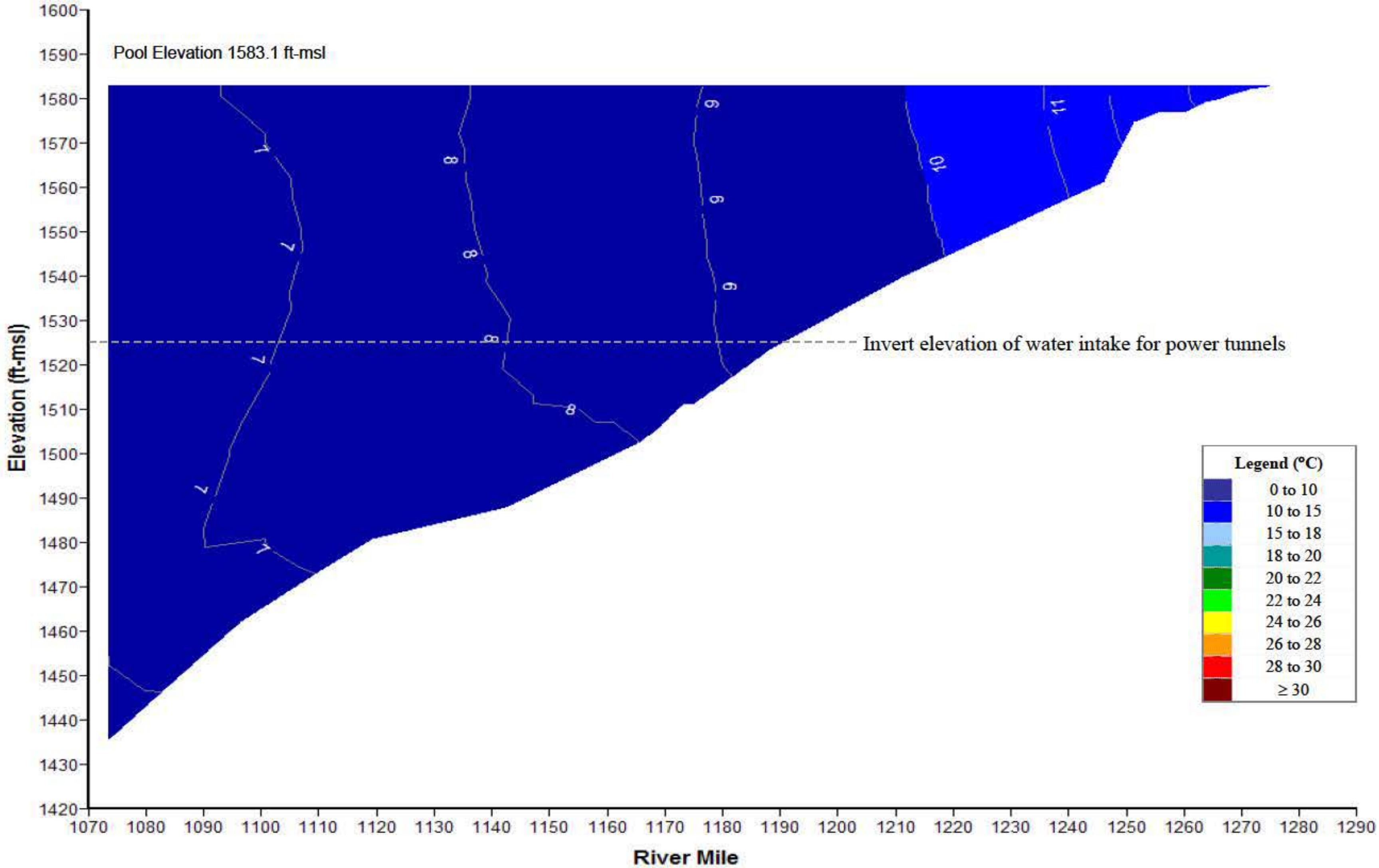


Plate 140. Longitudinal water temperature (°C) contour plot of Oahe Reservoir based on depth-profile water temperatures measured at sites OAHLK1073A, OAHLK1110DW, OAHLK1153DW, OAHLK1196DW and OAHNFMORR1 on May 13, 2008.

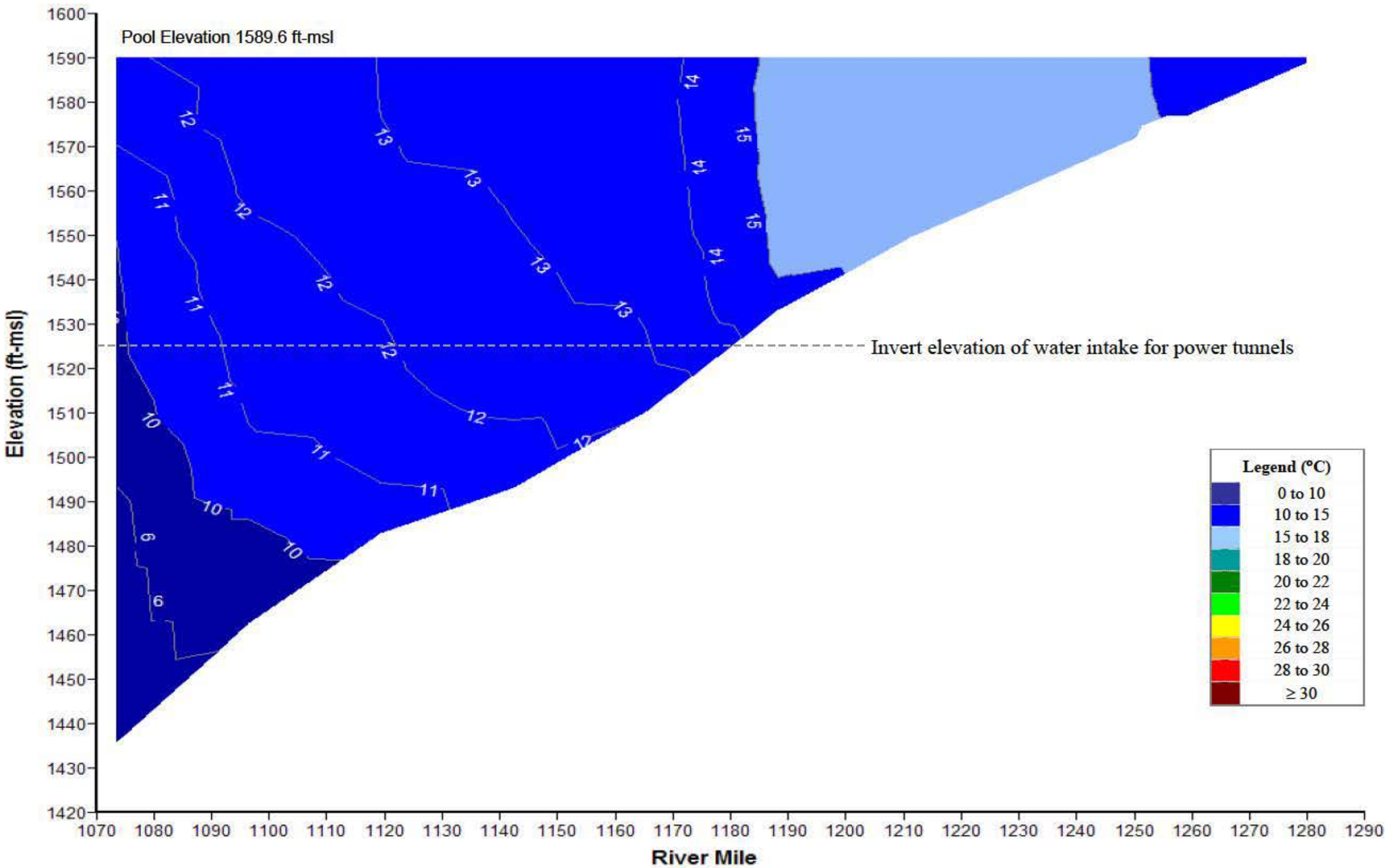


Plate 141. Longitudinal water temperature (°C) contour plot of Oahe Reservoir based on depth-profile water temperatures measured at sites OAHLK1073A, OAHLK1110DW, OAHLK1153DW, OAHLK1196DW and OAHNFMORR1 on June 11, 2008.

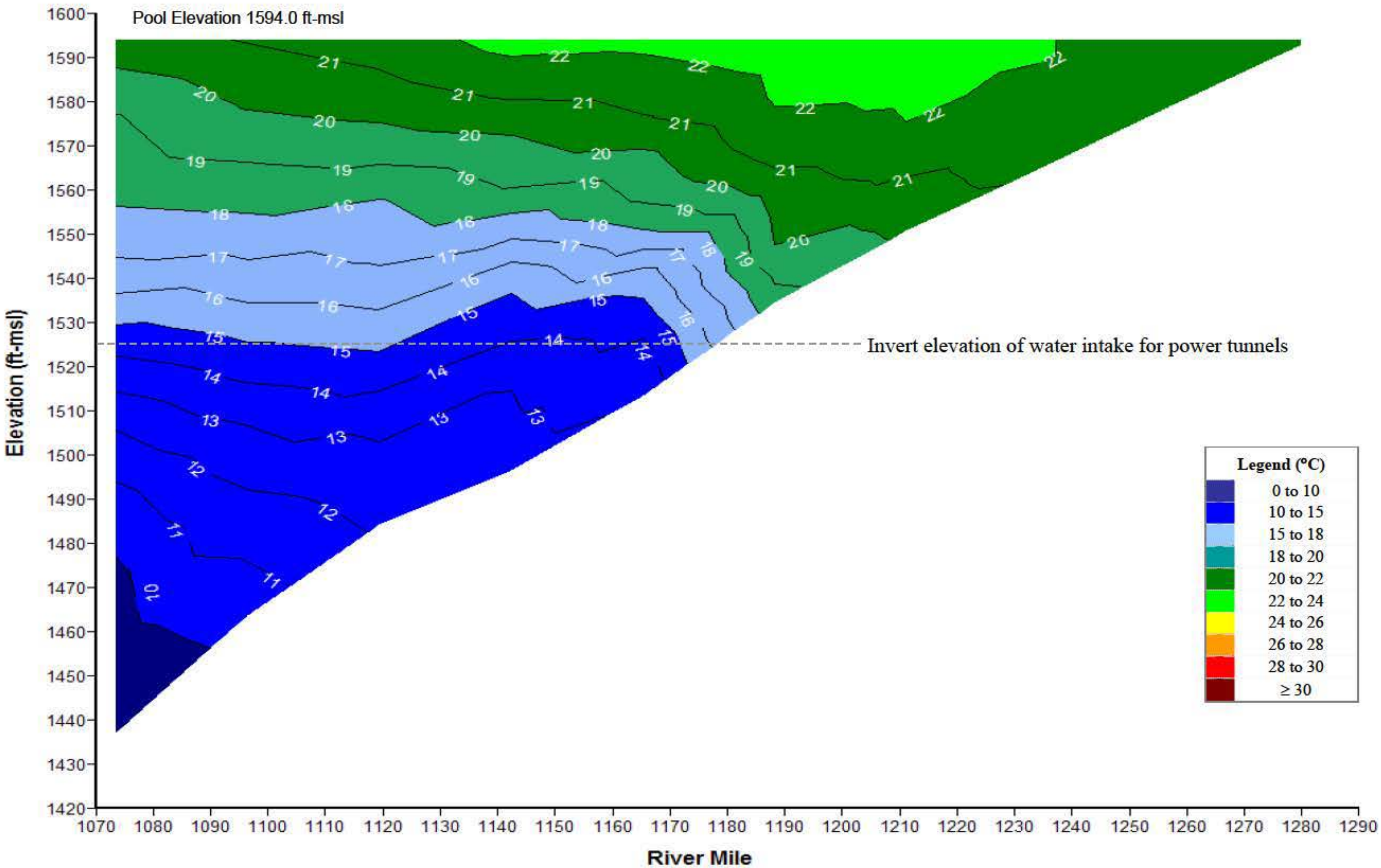


Plate 142. Longitudinal water temperature (°C) contour plot of Oahe Reservoir based on depth-profile water temperatures measured at sites OAHLK1073A, OAHLK1090DW, OAHLK1110DW, OAHLK1153DW, OAHLK1196DW and OAHNFMORR1 on July 17, 2008.

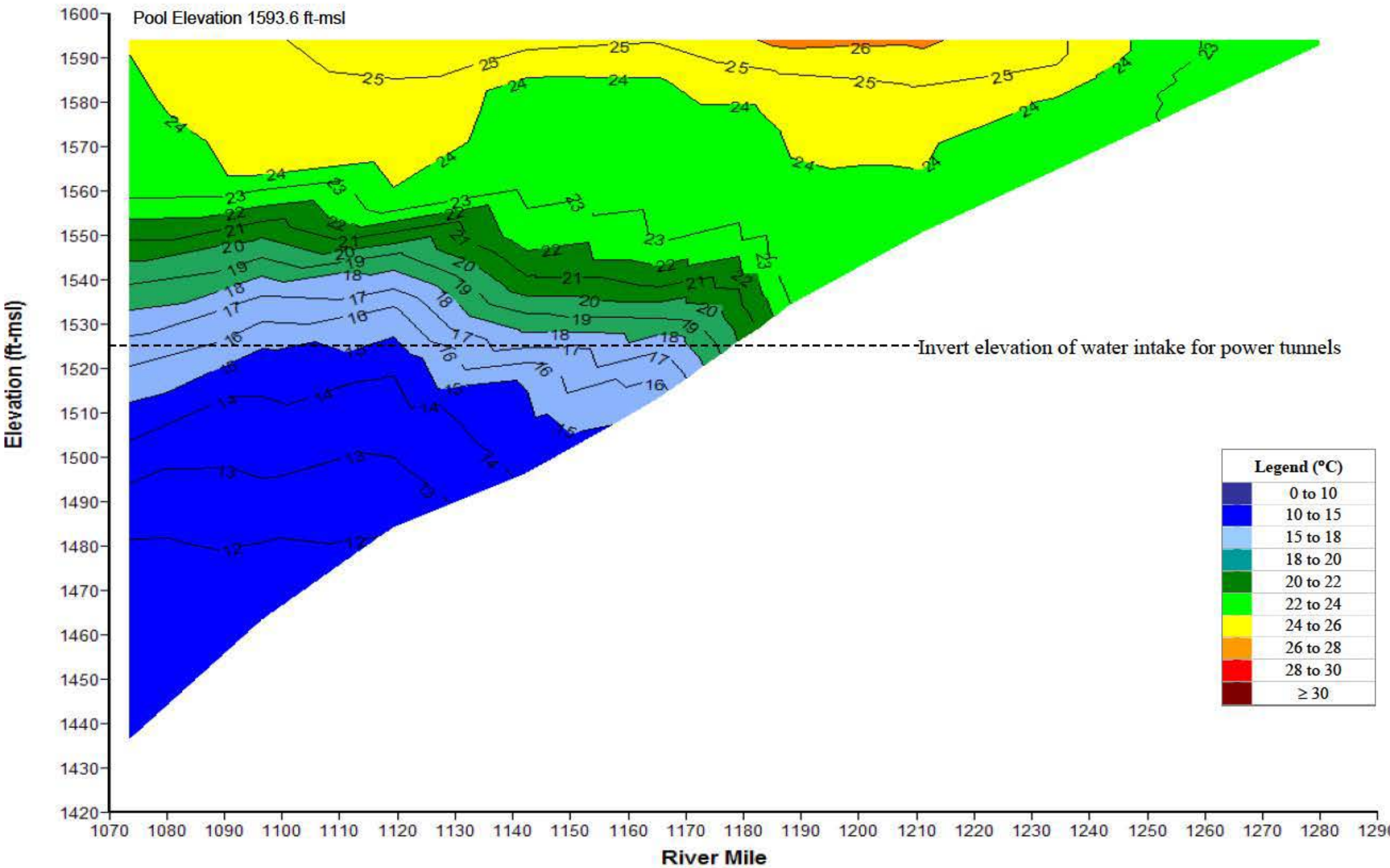


Plate 143. Longitudinal water temperature (°C) contour plot of Oahe Reservoir based on depth-profile water temperatures measured at sites OAHLK1073A, OAHLK1090DW, OAHLK1110DW, OAHLK1153DW, OAHLK1196DW and OAHNFMORR1 on August 13, 2008.

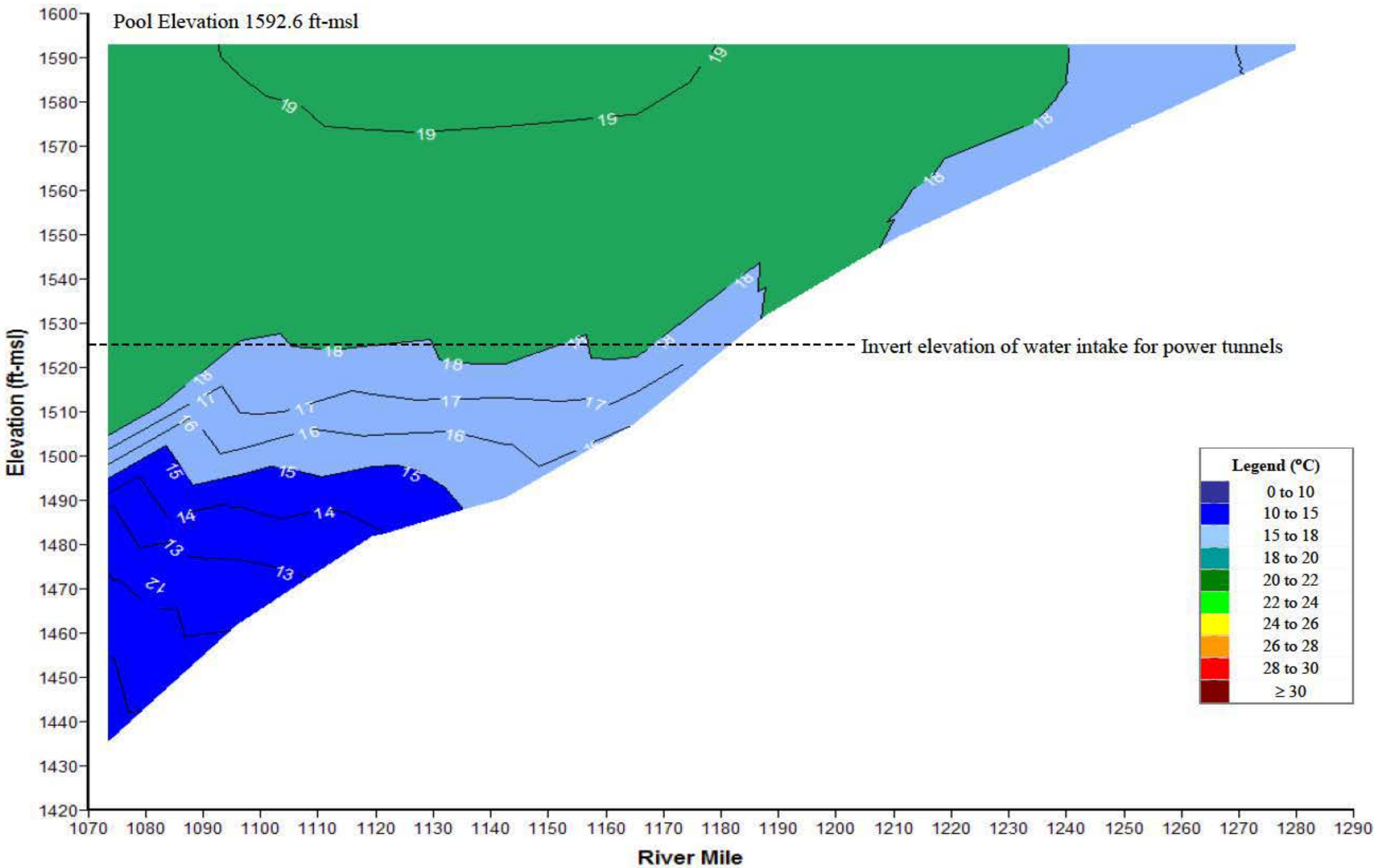


Plate 144. Longitudinal water temperature (°C) contour plot of Oahe Reservoir based on depth-profile water temperatures measured at sites OAHLK1073A, OAHLK1110DW, OAHLK1153DW, OAHLK1196DW and OAHNFMORR1 on September 17, 2008.

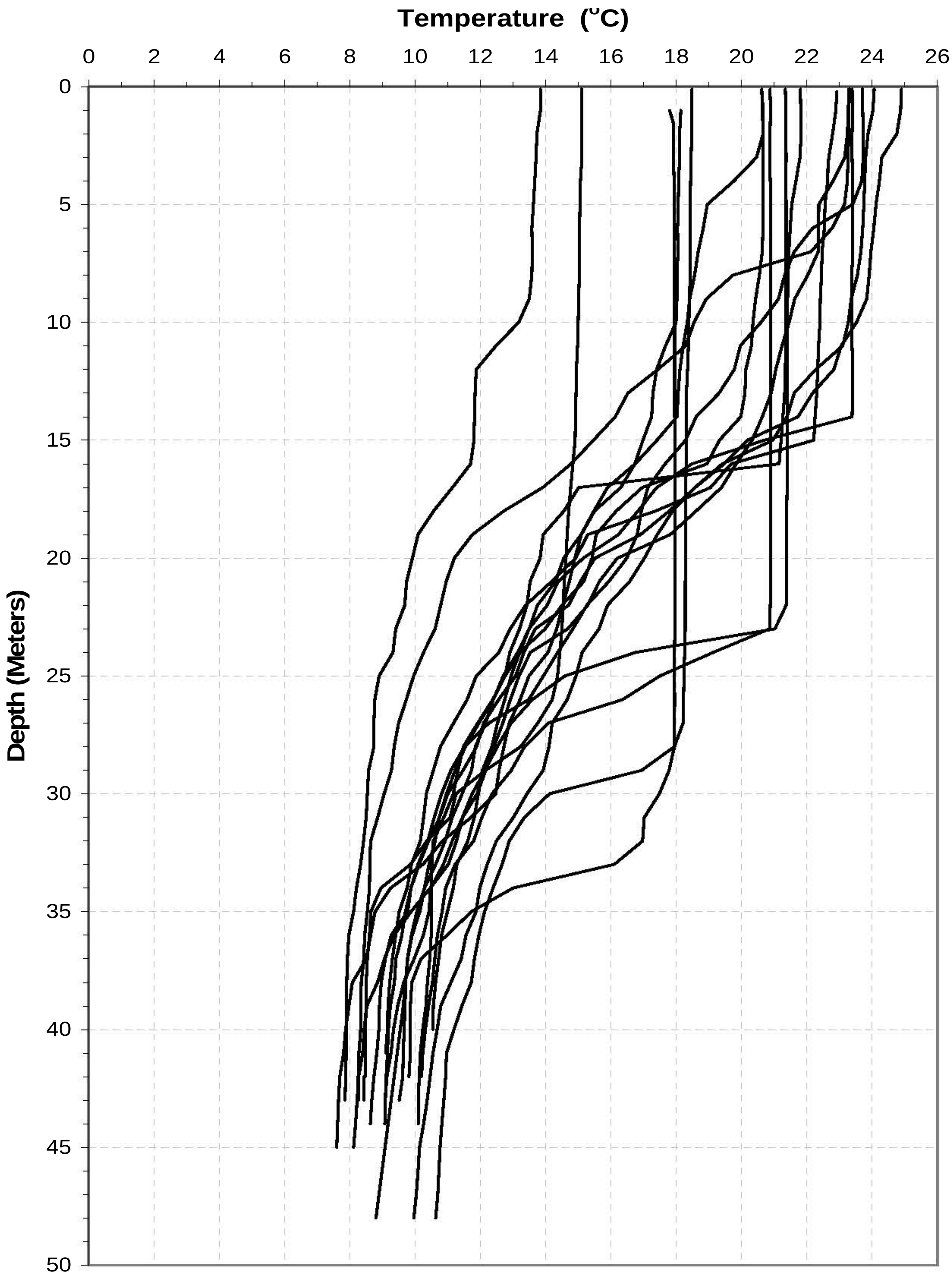


Plate 145. Temperature depth profiles for Oahe Reservoir generated from data collected at the near-dam, deepwater ambient monitoring site (i.e., OAHLK1073A) during the summer months over the 5-year period of 2004 to 2008**.**

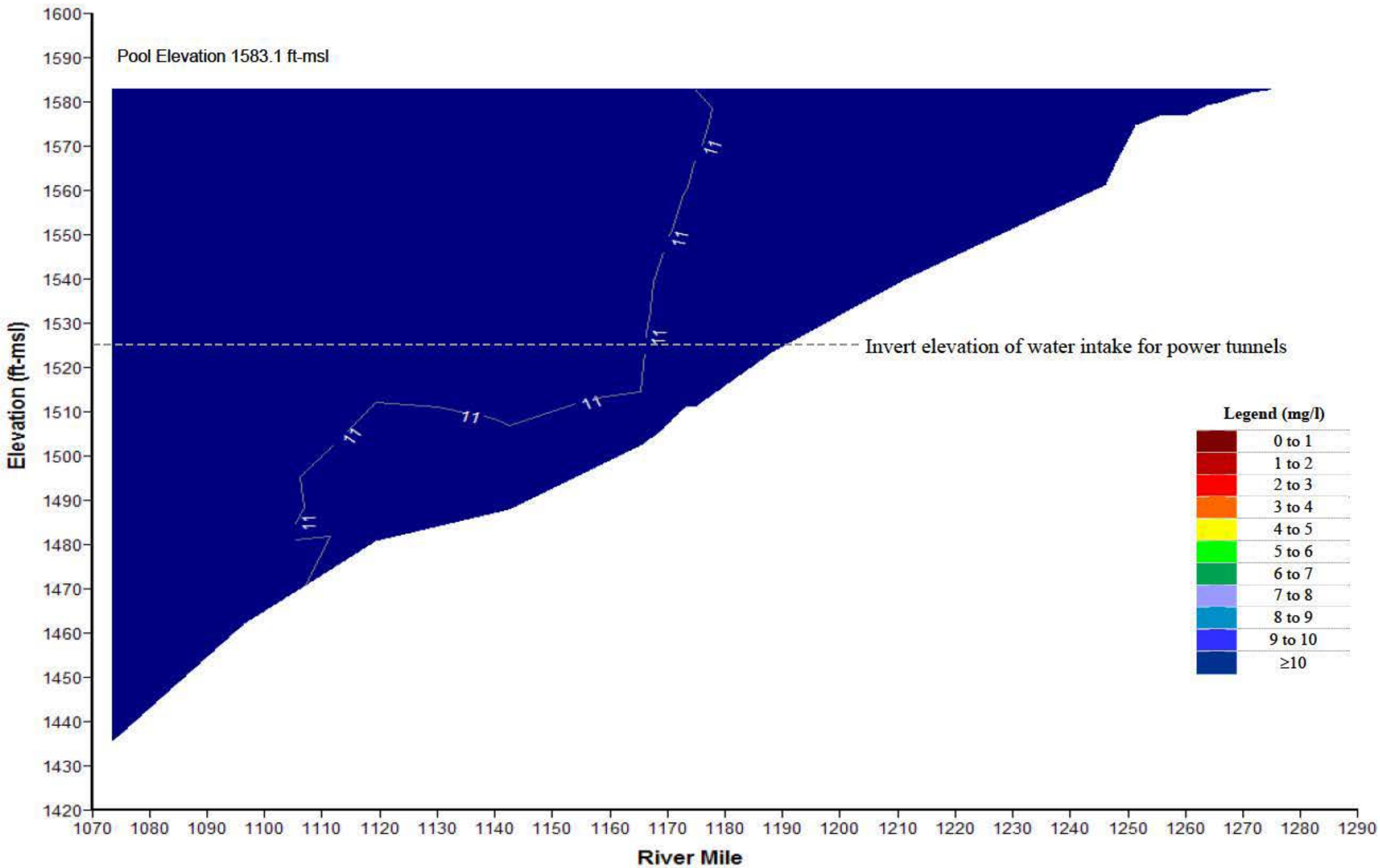


Plate 146. Longitudinal dissolved oxygen (mg/l) contour plot of Oahe Reservoir based on depth-profile dissolved oxygen concentrations measured at sites OAHLK1073A, OAHLK1110DW, OAHLK1153DW, OAHLK1196DW and OAHNFMORR1 on May 13, 2008.

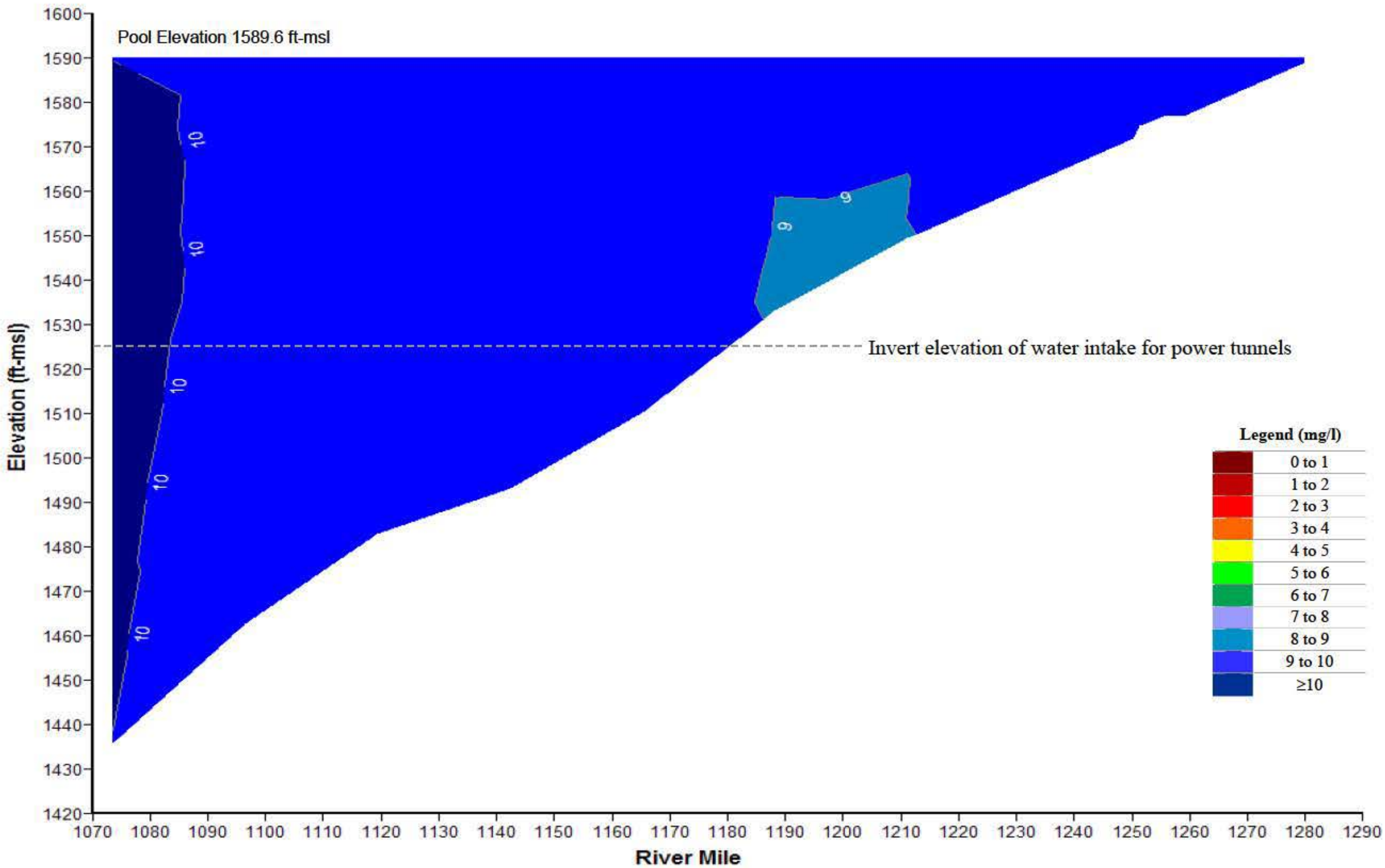


Plate 147. Longitudinal dissolved oxygen (mg/l) contour plot of Oahe Reservoir based on depth-profile dissolved oxygen concentrations measured at sites OAHLK1073A, OAHLK1110DW, OAHLK1153DW, OAHLK1196DW and OAHNFMORR1 on June 11, 2008.

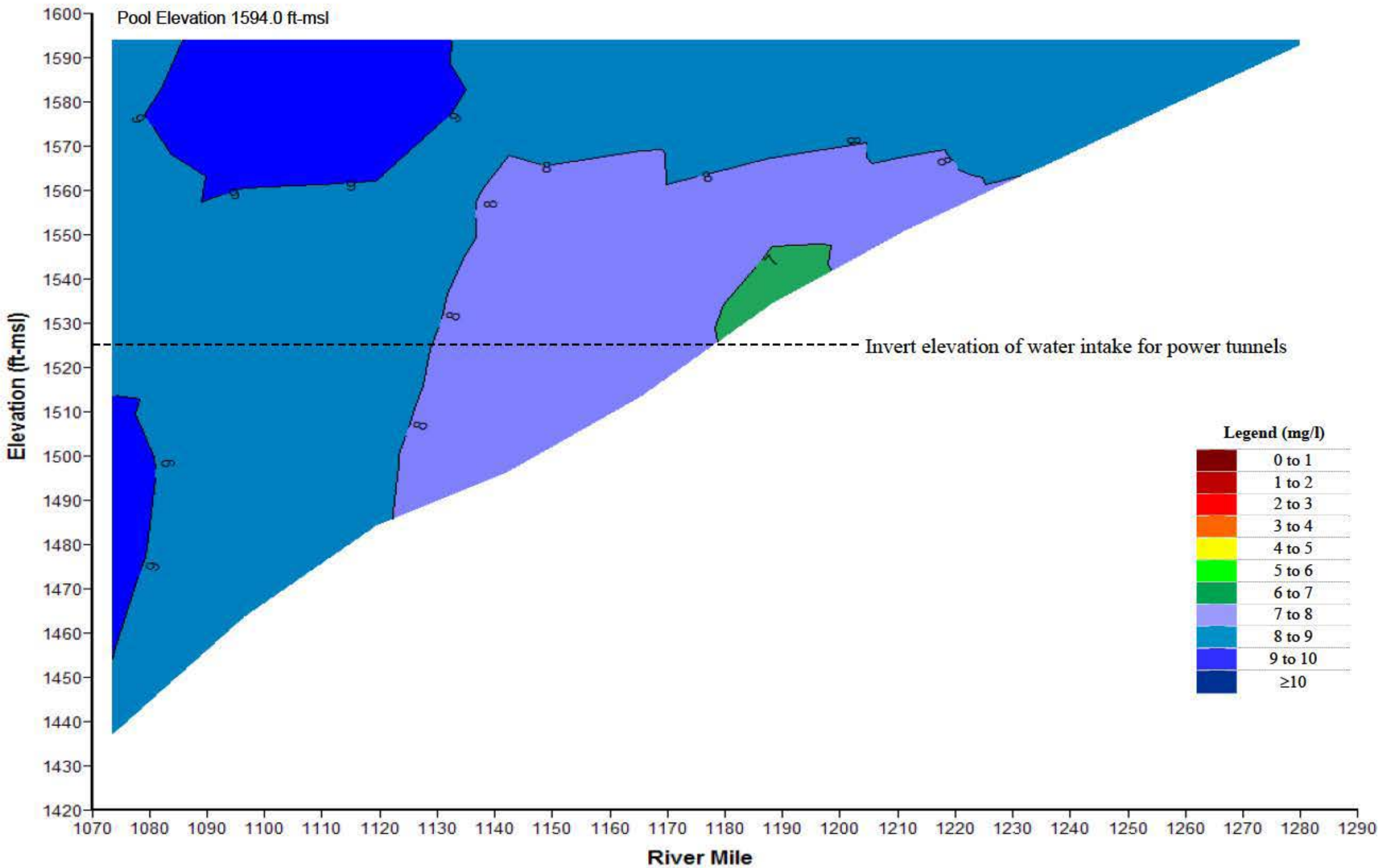


Plate 148. Longitudinal dissolved oxygen (mg/l) contour plot of Oahe Reservoir based on depth-profile dissolved oxygen concentrations measured at sites OAHLK1073A, OAHLK1110DW, OAHLK1153DW, OAHLK1196DW and OAHNFMORR1 on July 17, 2008.

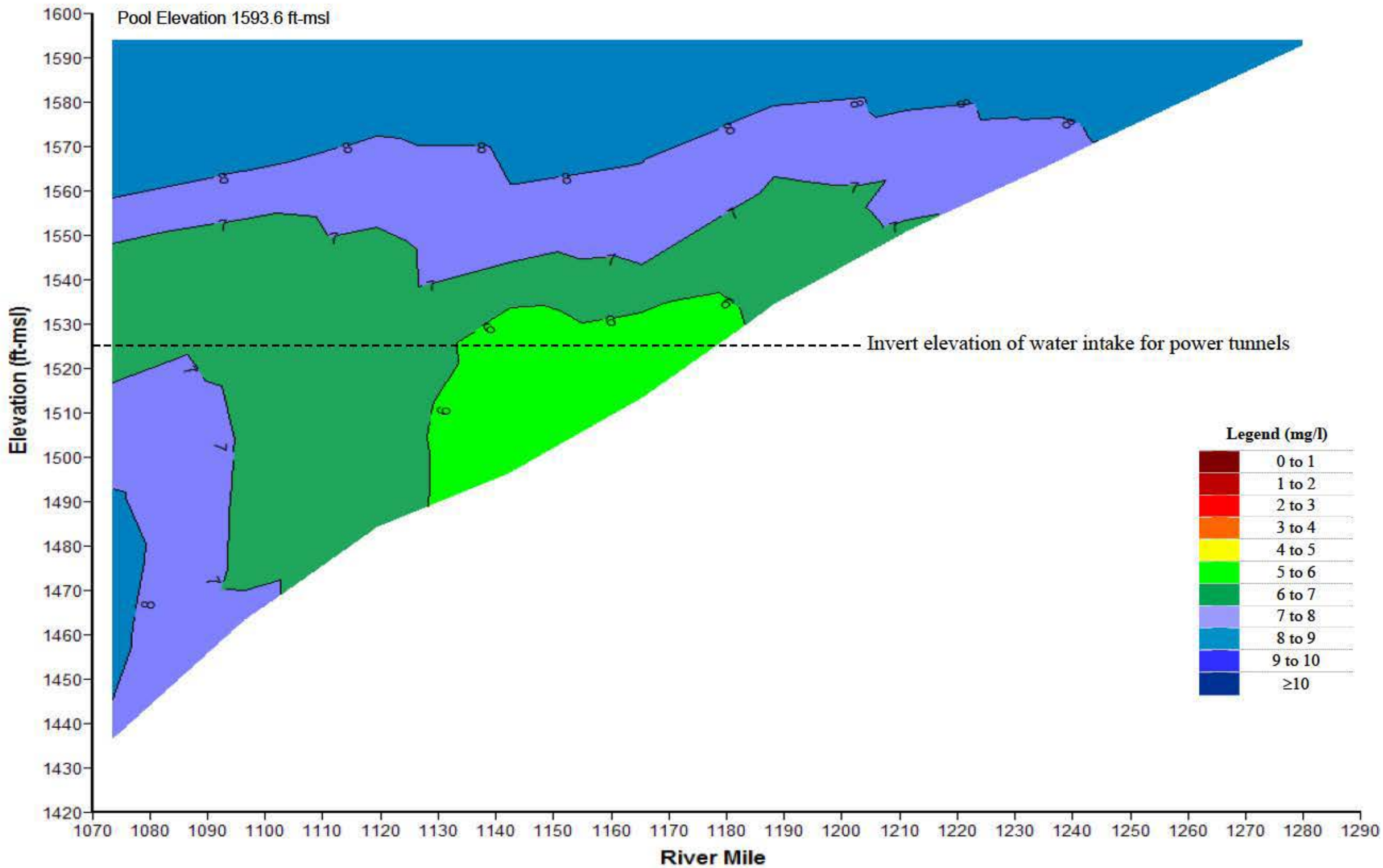


Plate 149. Longitudinal dissolved oxygen (mg/l) contour plot of Oahe Reservoir based on depth-profile dissolved oxygen concentrations measured at sites OAHLK1073A, OAHLK1110DW, OAHLK1153DW, OAHLK1196DW and OAHNFMORR1 on August 13, 2008.

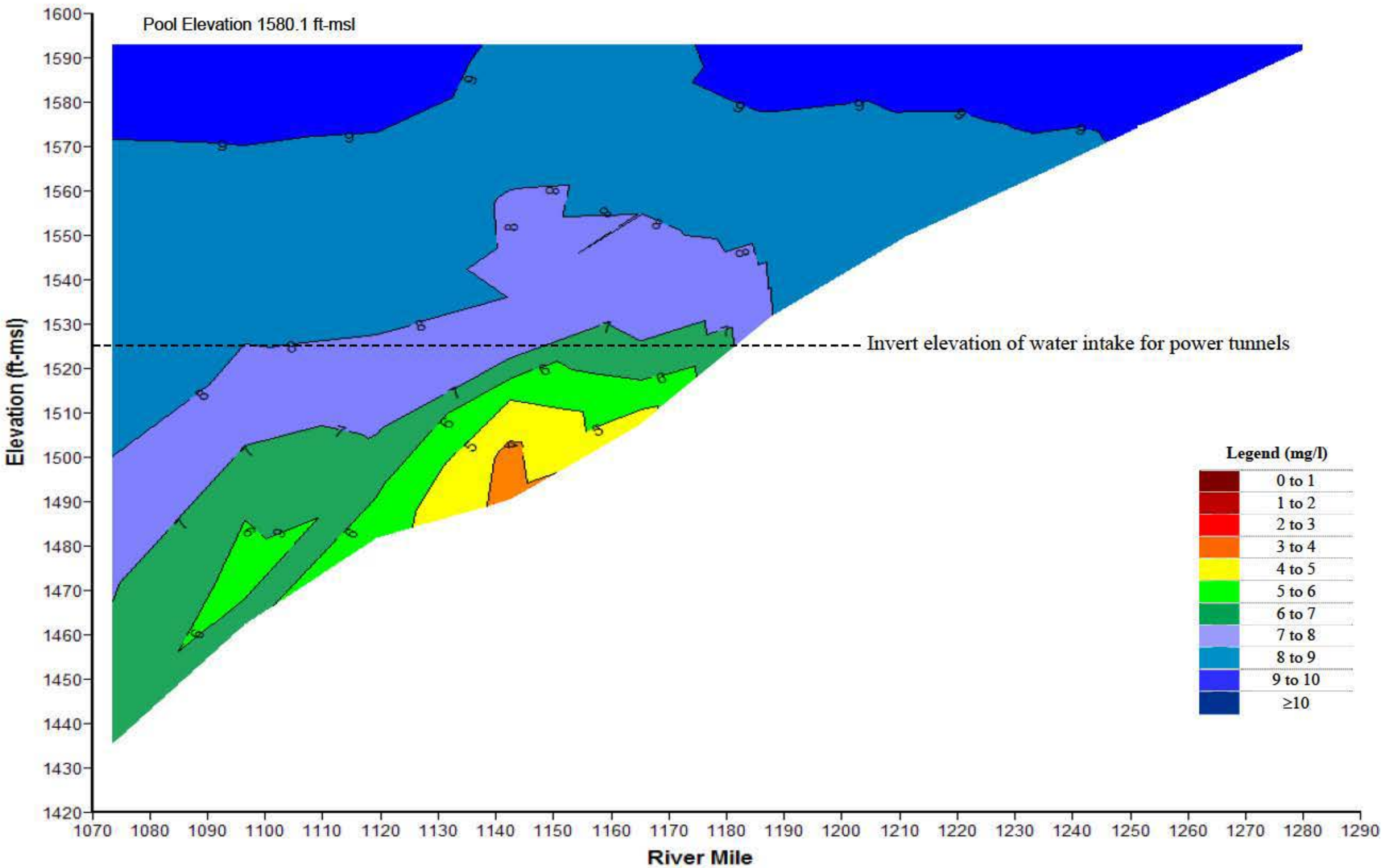


Plate 150. Longitudinal dissolved oxygen (mg/l) contour plot of Oahe Reservoir based on depth-profile dissolved oxygen concentrations measured at sites OAHLK1073A, OAHLK1110DW, OAHLK1153DW, OAHLK1196DW and OAHNFMORR1 on September 17, 2008.

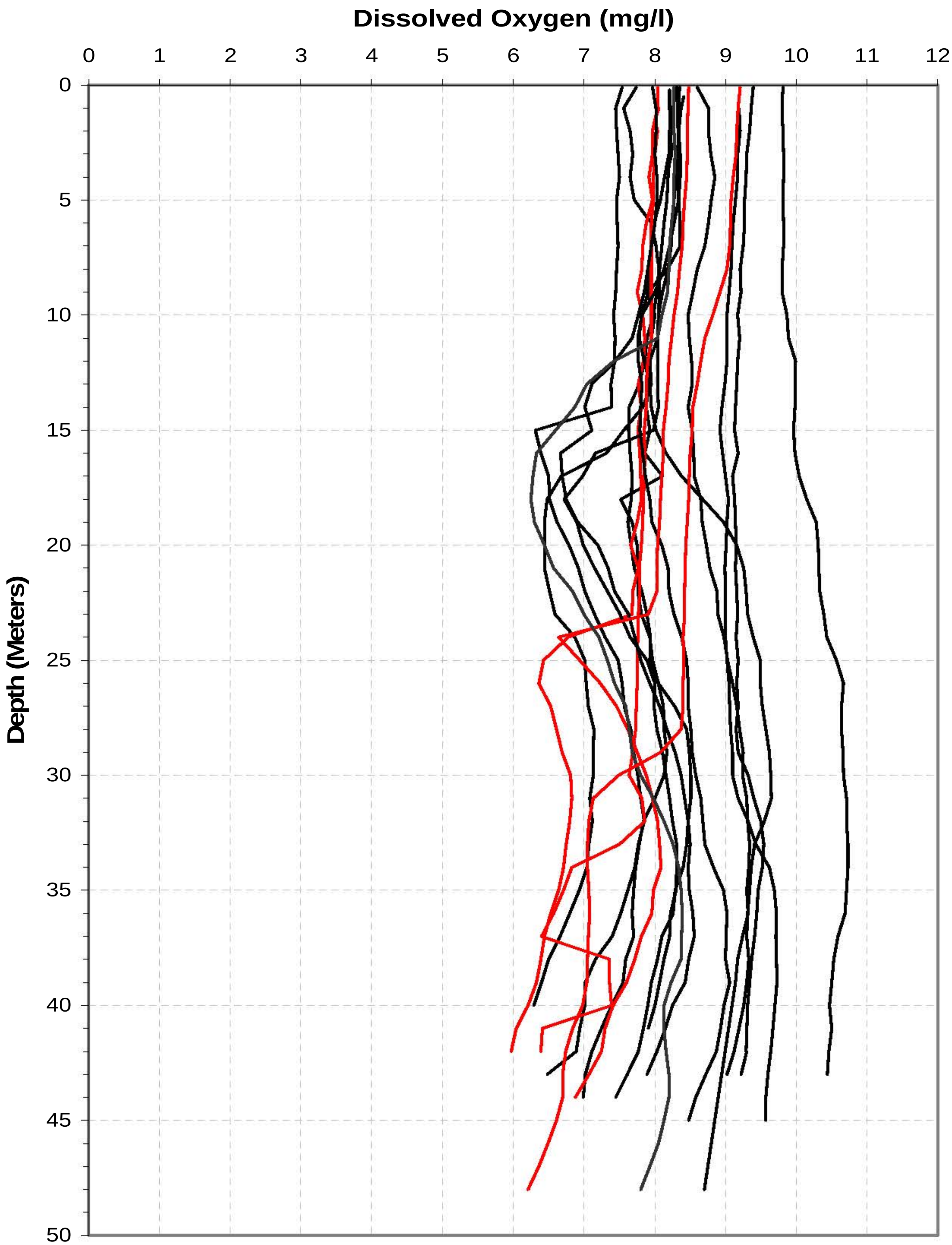


Plate 151. Dissolved oxygen depth profiles for Oahe Reservoir generated from data collected at the near-dam, deepwater ambient monitoring site (i.e., OAHLK1073A) during the summer months of the 5-year period of 2004 to 2008.
(Note: Red profile plots were measured in the month of September.)

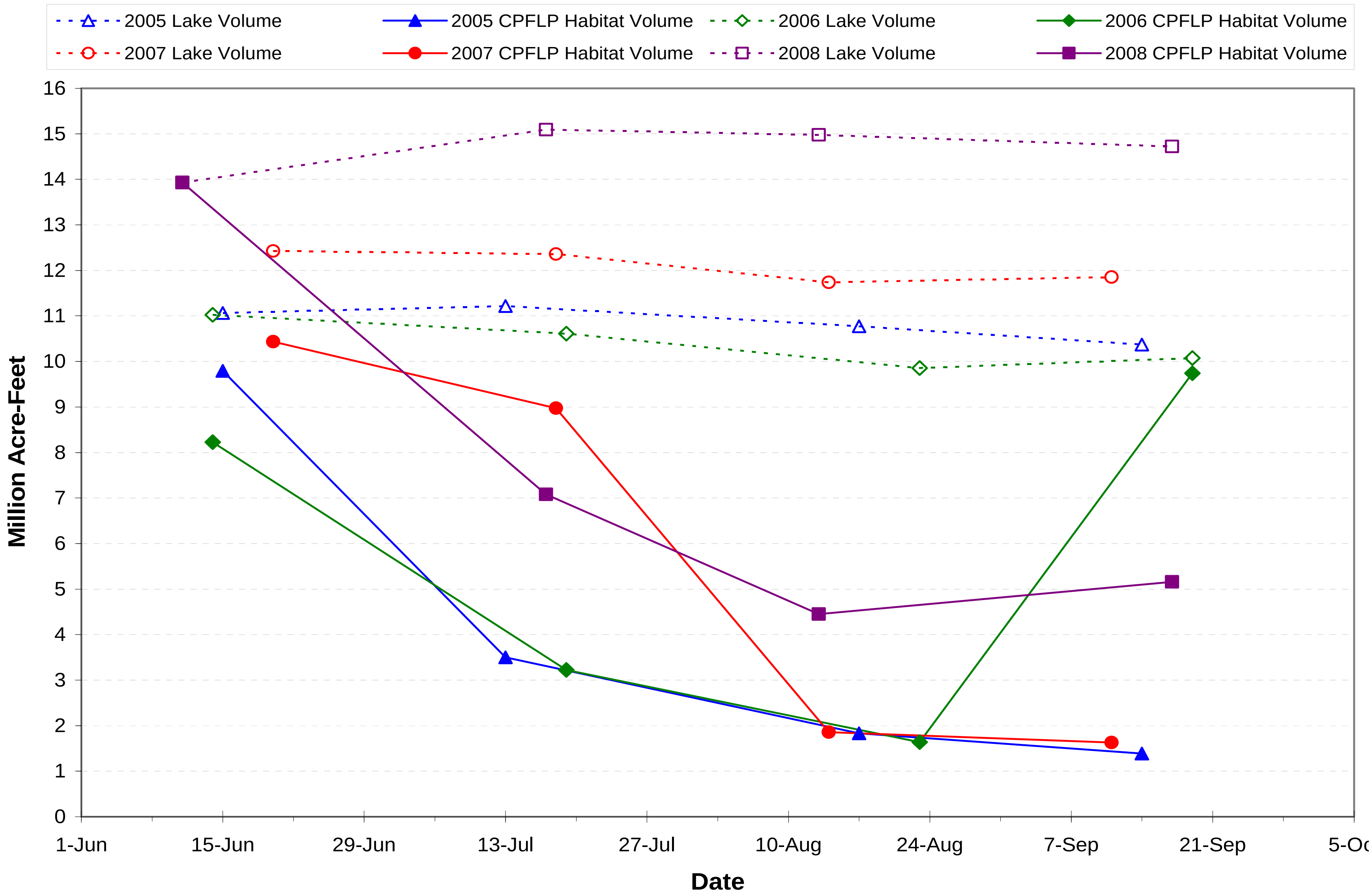


Plate 152. Estimated volume of Coldwater Permanent Fish Life Propagation habitat in Oahe Reservoir during 2005, 2006, 2007, and 2008.

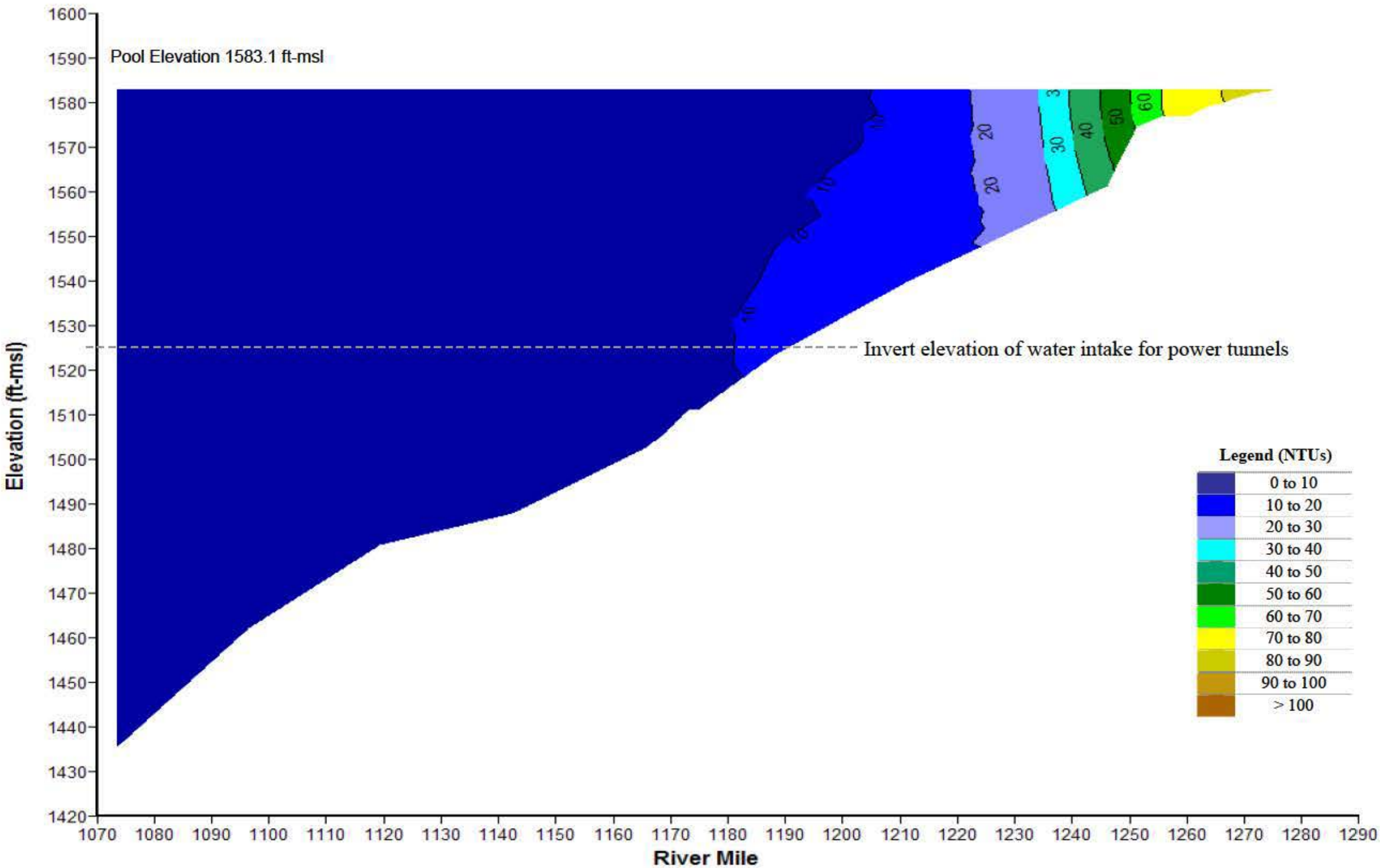


Plate 153. Longitudinal turbidity (NTU) contour plot of Oahe Reservoir based on depth-profile turbidity levels measured at sites OAHLK1073A, OAHLK1110DW, OAHLK1153DW, OAHLK1196DW and OAHNFMORR1 on May 13, 2008.

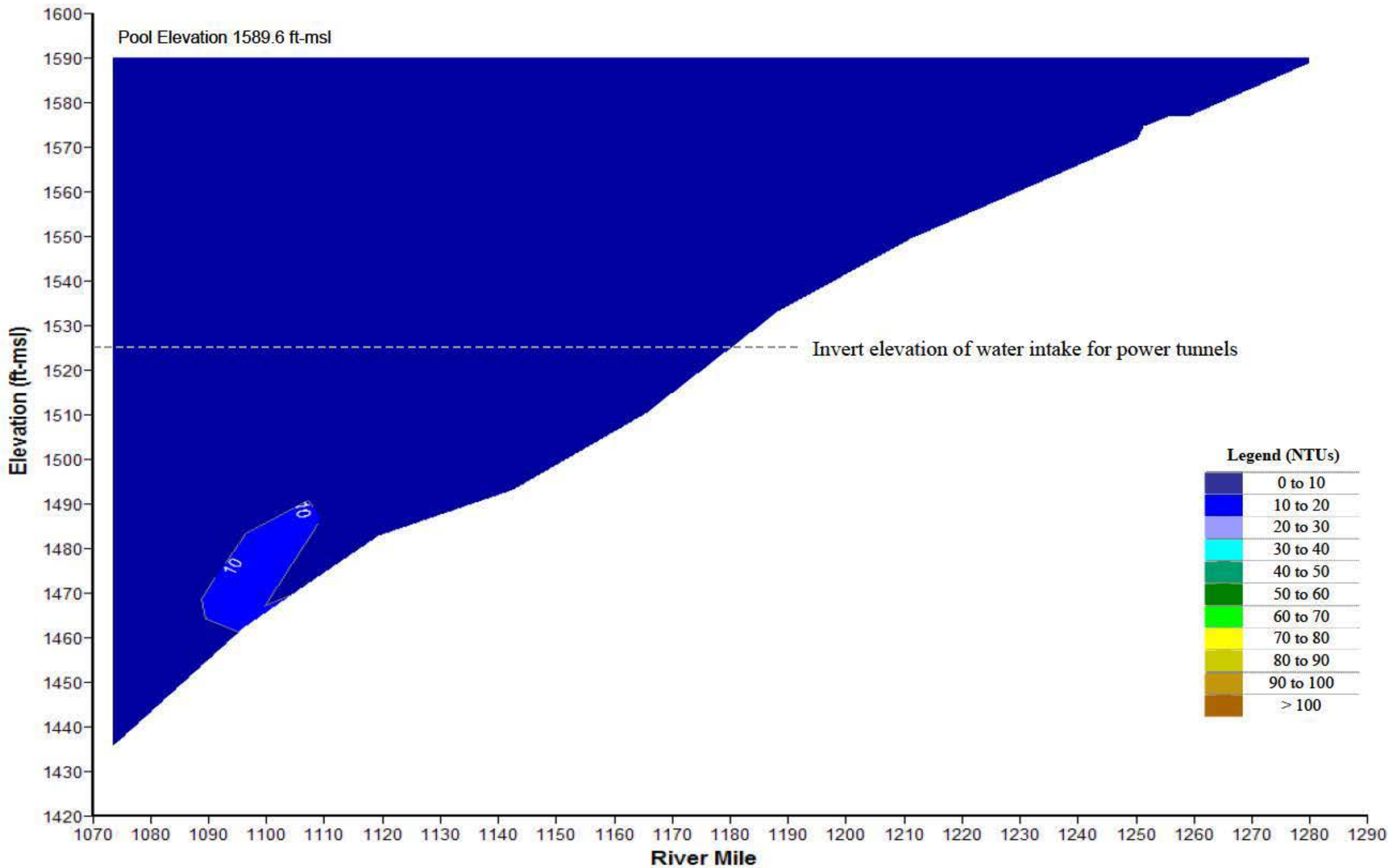


Plate 154. Longitudinal turbidity (NTU) contour plot of Oahe Reservoir based on depth-profile turbidity levels measured at sites OAHLK1073A, OAHLK1110DW, OAHLK1153DW, OAHLK1196DW and OAHNFMORR1 on June 11, 2008.

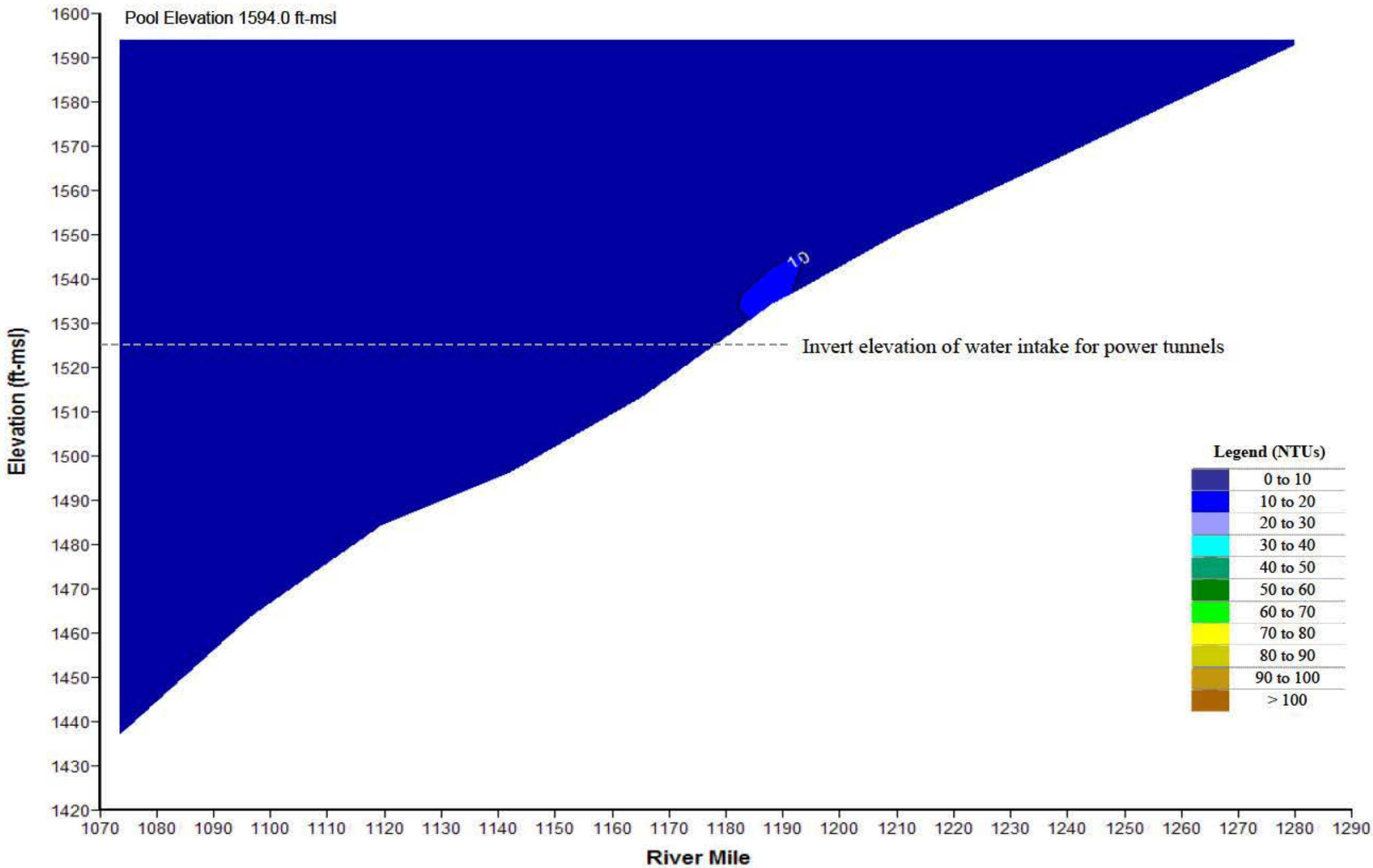


Plate 155. Longitudinal turbidity (NTU) contour plot of Oahe Reservoir based on depth-profile turbidity levels measured at sites OAHLK1073A, OAHLK1110DW, OAHLK1153DW, OAHLK1196DW and OAHNFMORR1 on July 17, 2008.

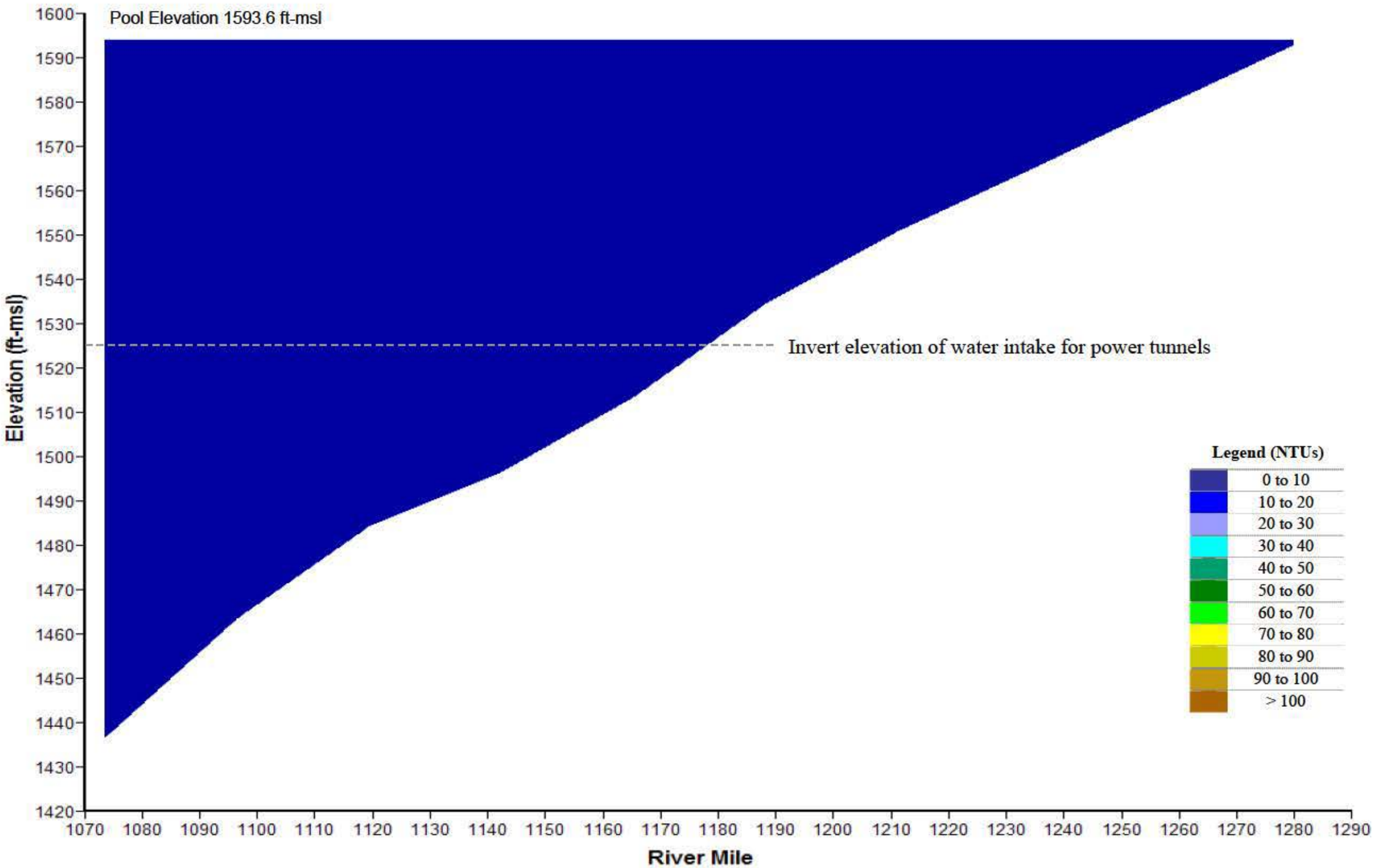


Plate 156. Longitudinal turbidity (NTU) contour plot of Oahe Reservoir based on depth-profile turbidity levels measured at sites OAHLK1073A, OAHLK1110DW, OAHLK1153DW, OAHLK1196DW and OAHNFMORR1 on August 13, 2008.

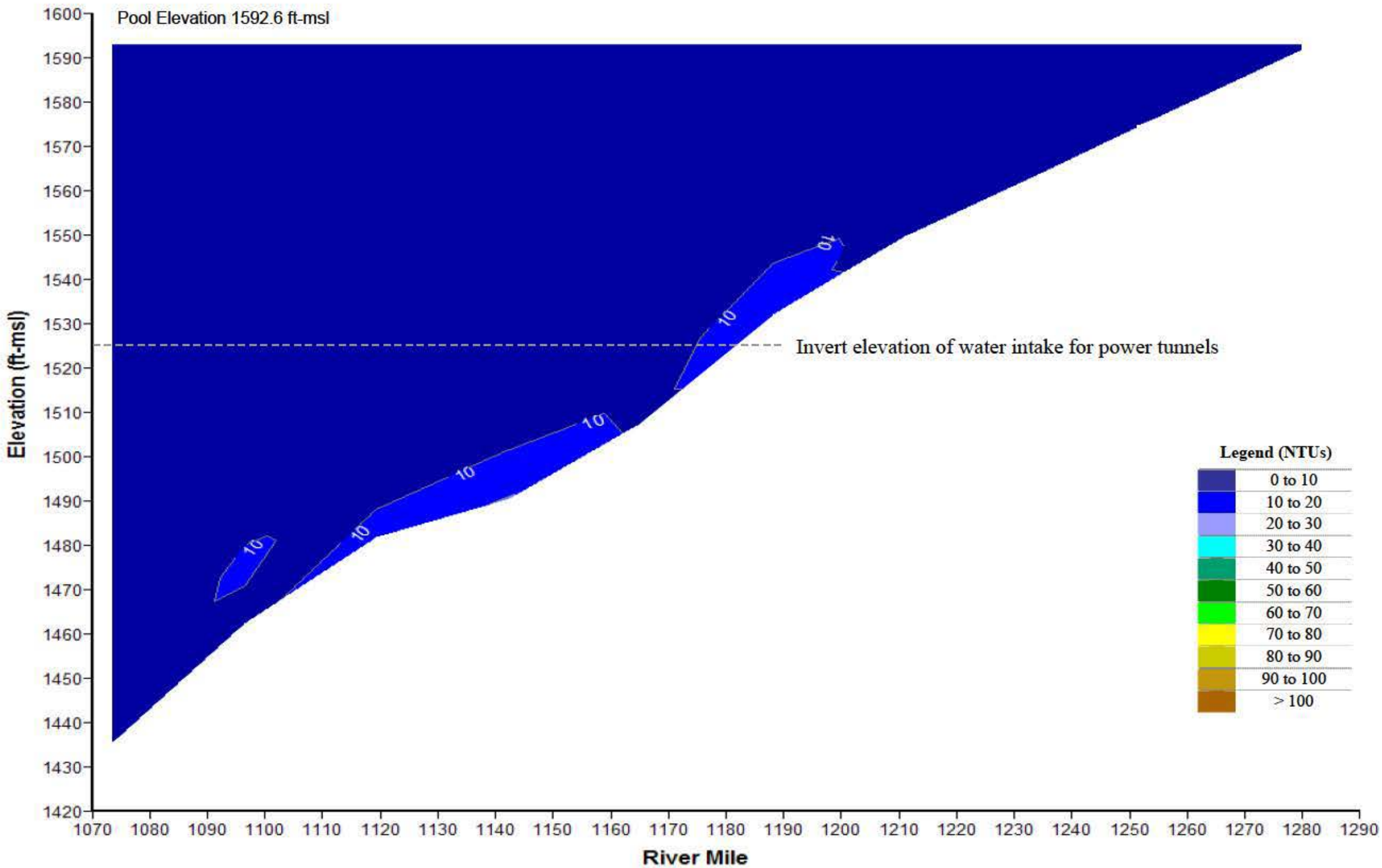


Plate 157. Longitudinal turbidity (NTU) contour plot of Oahe Reservoir based on depth-profile turbidity levels measured at sites OAHLK1073A, OAHLK1110DW, OAHLK1153DW, OAHLK1196DW and OAHNFMORR1 on September 17, 2008.

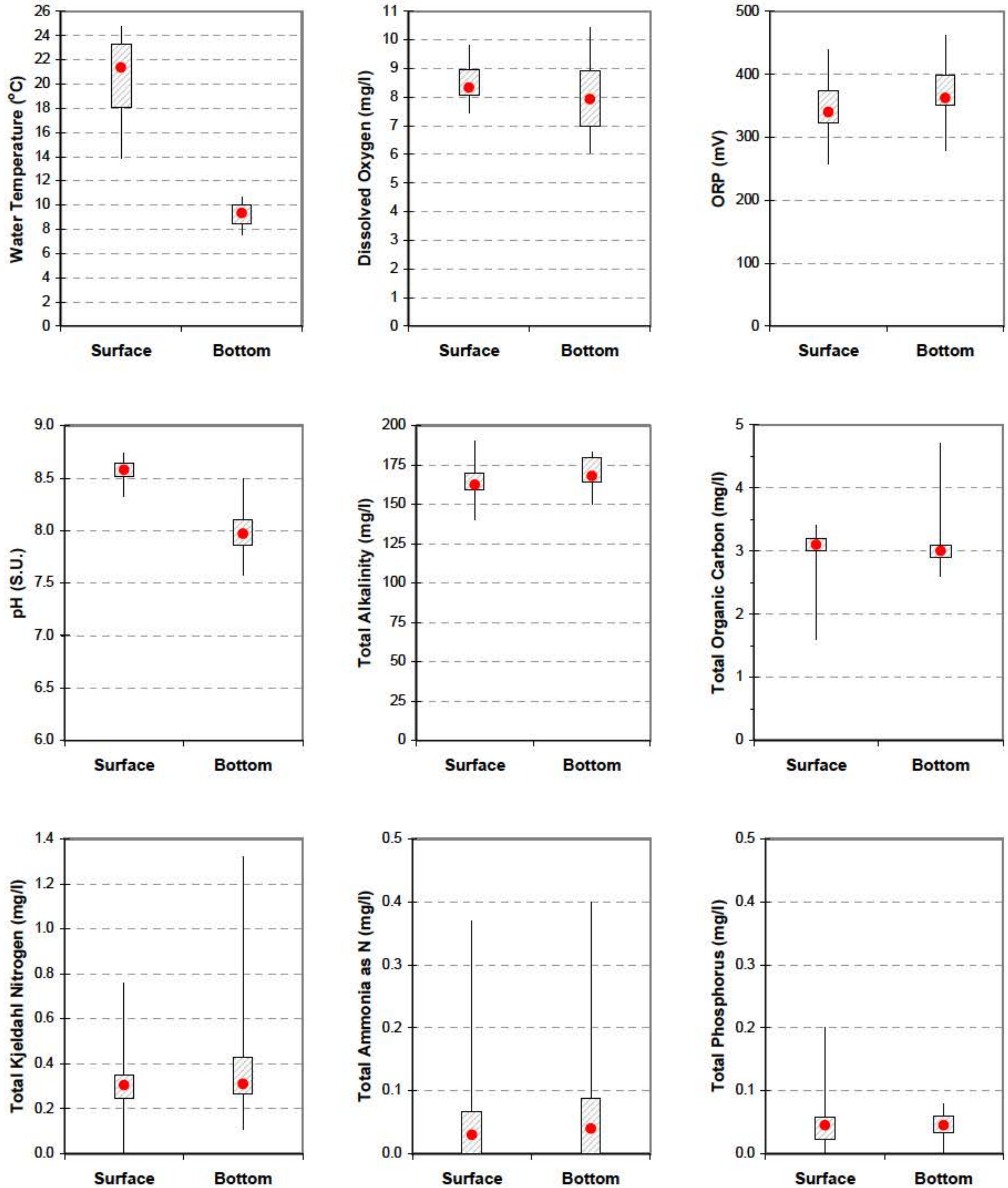


Plate 158. Box plots comparing paired surface and bottom water temperature, dissolved oxygen, oxidation-reduction potential, pH, alkalinity, total organic carbon, total Kjeldahl nitrogen, total ammonia nitrogen, and total phosphorus measurements taken in Oahe Reservoir at site OAHLK1073A during the summer months of 2004 through 2008.
(Box plots display minimum, 25th percentile, 75th percentile, and maximum. Median value is indicated by the red dot.)

Plate 159. Total biovolume, number of genera present, and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected in Oahe Reservoir at site OAHLK1073A during the 5-year period 2004 through 2008.

Date	Total Sample Biovolume (um^3)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta		Shannon-Weaver Genera Diversity
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	
Jun 2004	7,414,456	2	0.19	0	-----	0	-----	1	0.14	4	0.37	1	0.30	0	-----	1.48
Jul 2004	4,313,125	2	0.14	0	-----	0	-----	2	0.75	3	0.11	0	-----	0	-----	1.25
Aug 2004	164,005,921	4	0.78	0	-----	1	0.07	1	0.02	3	<0.01	1	0.14	0	-----	0.85
Sep 2004	5,604,589	2	0.38	1	0.04	0	-----	1	0.03	3	0.35	0	-----	1	0.20	1.45
May 2005	185,149,541	3	0.96	2	0.01	1	<0.01	1	0.03	0	-----	0	-----	0	-----	0.96
Jun 2005	55,201,496	4	0.58	1	0.8	0	-----	1	0.11	3	0.02	1	0.22	0	-----	1.78
Jul 2005	45,943,019	4	0.31	2	0.04	1	0.35	1	0.04	3	0.02	1	0.25	0	-----	1.73
Aug 2005	37,779,368	5	0.84	1	0.12	0	-----	0	-----	3	0.04	0	-----	0	-----	1.58
Sep 2005	100,194,654	9	0.46	7	0.09	2	0.14	2	0.04	4	0.22	1	0.05	0	-----	2.39
May 2006	186,720,908	8	0.97	3	0.01	0	-----	1	0.01	0	-----	1	0.02	0	-----	1.31
Jun 2006	95,437,433	5	0.76	6	0.18	0	-----	1	0.05	0	-----	0	-----	1	0.01	1.52
Jul 2006	21,592,424	4	0.17	8	0.46	0	-----	1	0.29	2	0.08	0	-----	0	-----	2.25
Aug 2006	52,731,261	5	0.42	2	0.06	1	0.08	1	0.11	3	0.11	1	0.22	0	-----	2.05
Sep 2006	72,290,329	5	0.12	7	0.26	0	-----	1	0.17	2	0.26	1	0.19	0	-----	2.06
May 2007	116,487,228	7	0.69	5	0.16	2	0.04	1	0.10	0	-----	1	0.01	0	-----	2.09
Jun 2007	688,764,256	4	0.85	6	0.03	2	0.09	1	0.02	0	-----	2	0.02	0	-----	1.03
Jul 2007	112,682,481	9	0.71	7	0.04	0	-----	1	0.12	0	-----	2	0.12	0	-----	1.52
Aug 2007	45,414,995	3	0.04	7	0.08	1	0.11	1	0.35	2	0.07	1	0.35	0	-----	1.63
Sep 2007	211,489,007	5	0.40	10	0.03	1	0.11	2	0.01	5	0.03	1	0.41	0	-----	1.45
May 2008	232,958,831	6	0.96	3	<0.01	0	-----	1	0.03	0	-----	0	-----	0	-----	1.00
Jun 2008	224,849,023	10	0.96	3	0.01	1	<0.01	1	0.02	0	-----	1	0.01	0	-----	0.95
Jul 2008	187,175	6	0.85	5	0.03	1	0.02	0	-----	0	-----	1	0.09	0	-----	1.17
Aug 2008	13,908,908	2	0.03	3	0.18	1	0.32	1	0.45	2	0.01	0	-----	0	-----	1.31
Sep 2008	273,503,287	8	0.80	11	0.03	2	0.01	2	0.07	2	0.01	2	0.09	1	<0.01	0.98
Mean*	**123,109,321**	**5.1**	**0.56**	**4.2**	**0.13**	**0.7**	**0.10**	**1.1**	**0.13**	**1.8**	**0.11**	**0.8**	**0.16**	**0.1**	**0.07**	**1.49**

* Mean percent composition represents the mean when taxa of that division are present.

Plate 160. Total biovolume, number of genera present, and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected in Oahe Reservoir at site OAHLK1110DW during the 4-year period 2005 through 2008.

Date	Total Sample Biovolume (um^3)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta		Shannon-Weaver Genera Diversity
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	
Jun 2005	312,053,421	4	0.84	3	0.08	1	<0.01	2	0.06	4	0.02	0	-----	0	-----	1.06
Aug 2005	140,479,427	6	0.30	2	0.08	1	0.07	1	0.29	2	0.05	2	0.22	0	-----	2.16
Sep 2005	162,991,360	5	0.35	4	0.08	1	<0.01	2	0.10	4	0.25	2	0.22	0	-----	2.02
Jun 2006	546,334,257	6	0.97	5	0.01	2	<0.01	1	0.02	3	<0.01	1	<0.01	0	-----	0.64
Jul 2006	83,678,531	6	0.14	3	0.22	0	-----	1	0.19	4	0.20	2	0.24	0	-----	2.19
Aug 2006	300,970,747	6	0.46	5	0.09	0	-----	1	<0.01	3	0.41	1	0.04	0	-----	1.88
Sep 2006	168,663,712	6	0.22	15	0.30	1	0.02	1	0.30	3	0.04	2	0.12	2	<0.01	2.53
Jun 2007	2,874,771,946	6	0.88	7	0.01	2	0.07	1	0.01	0	-----	1	0.03	0	-----	1.05
Jul 2007	61,788,273	8	0.14	6	0.13	1	0.38	1	0.13	1	0.01	1	0.22	0	-----	1.80
Aug 2007	189,011,871	7	0 31	10	0.10	0	-----	1	0.09	1	0.30	1	0.20	1	<0.01	1.99
Sep 2007	127,037,794	5	0.13	8	0.06	1	0.02	1	0.06	6	0.16	1	0.56	1	0.01	1.75
May 2008	419,015,484	7	0.97	1	<0.01	1	<0.01	1	0.03	0	-----	1	<0.01	0	-----	0.65
Jun 2008	455,034,524	11	0.97	8	0.01	2	<0.01	1	0.01	2	<0.01	0	-----	0	-----	1.28
Jul 2008	199,124	3	0.67	12	0.14	1	0.07	1	0.06	0	-----	3	0.06	0	-----	1.71
Aug 2008	93,145,243	2	0.86	2	<0.01	1	<0.01	1	0.07	3	0.01	2	0.05	0	-----	0.60
Sep 2008	198,239,601	8	0.46	6	0.06	1	0.01	2	0.32	2	0.04	1	0.11	1	<0.01	1.74
Mean*	**383,338,457**	**6.0**	**0.54**	**6.1**	**0.09**	**1.0**	**0.05**	**1.2**	**0.11**	**2.4**	**0.11**	**1.3**	**0.15**	**0.3**	**<0.01**	**1.57**

* Mean percent composition represents the mean when taxa of that division are present.

Plate 161. Total biovolume, number of genera present, and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected in Oahe Reservoir at site OAHLK1153DW during the 4-year period 2005 through 2008.

Date	Total Sample Biovolume (um^3)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta		Shannon-Weaver Genera Diversity
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	
Jun 2005	2,103,413	0	-----	0	-----	0	-----	2	0.83	2	0.17	0	-----	0	-----	0.55
Jul 2005	121,465,212	5	0.44	2	0.02	1	0.50	2	0.04	2	<0.01	1	<0.01	0	-----	1.38
Aug 2005	375,380,230	5	0.79	8	0.14	0	-----	2	0.06	5	0.01	1	0.01	0	-----	1.10
Sep 2005	20,836,490	5	0.60	7	0.03	0	-----	1	0.16	5	0.16	1	0.06	0	-----	1.74
Jun 2006	2,880,967,056	8	0.74	13	0.25	1	<0.01	1	<0.01	1	<0.01	1	<0.01	0	-----	0.98
Jul 2006	404,261,840	3	0.87	6	0.03	1	0.02	1	0.03	2	0.03	1	0.02	0	-----	0.70
Aug 2006	116,503,830	7	0 22	10	0.28	1	<0.01	1	0.14	5	0.31	2	0.04	1	<0.01	2.38
Sep 2006	121,255,178	6	0.52	12	0.25	0	-----	1	0.06	4	0.06	1	0.05	2	0.05	2.23
Jun 2007	1,767,149,650	10	0.93	10	0.06	1	<0.01	1	0.01	2	<0.01	1	<0.01	0	-----	0.55
Jul 2007	301,855,009	8	0.53	5	0.06	1	<0.01	1	0.06	2	0.11	1	0.22	1	0.02	1.55
Aug 2007	144,618,019	6	0.12	9	0.18	1	0.19	1	0.11	4	0.08	1	0.26	2	0.06	2.21
Sep 2007	231,862,268	5	0.74	14	0.13	0	-----	2	0.04	5	0.04	1	0.02	1	0.03	2.16
May 2008	1,111,689,197	15	0.99	1	<0.01	2	<0.01	1	0.01	0	-----	1	<0.01	0	-----	0.98
Jun 2008	559,678,249	8	0.99	5	<0.01	0	-----	1	0.01	1	<0.01	0	-----	0	-----	1.10
Jul 2008	142,699	2	0.61	7	0.12	1	0.01	1	0.12	2	0.01	1	0.13	0	-----	1.60
Aug 2008	119,345,010	6	0.87	1	0.01	2	0.02	1	0.04	2	0.05	1	0.01	0	-----	1.49
Sep 2008	369,704,260	5	0.60	9	0.08	0	-----	2	0.23	2	0.01	3	0.07	1	0.01	2.00
Mean*	**508,753,977**	**6.1**	**0.66**	**7.0**	**0.10**	**0.7**	**0.07**	**1.3**	**0.11**	**2.7**	**0.07**	**1.1**	**0.06**	**0.5**	**0.03**	**1.45**

* Mean percent composition represents the mean when taxa of that division are present.

Plate 162. Total biovolume, number of genera present, and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected in Oahe Reservoir at site OAHLK1196DW during the 4-year period 2005 through 2008.

Date	Total Sample Biovolume (um^3)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta		Shannon-Weaver Genera Diversity
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	
Jun 2005	120,198,449	6	0 96	2	0.02	0	-----	2	0.01	2	<0.01	0	-----	0	-----	1.63
Jul 2005	630,374,805	8	0.32	12	0.14	0	-----	2	0.31	7	0.20	1	0.04	0	-----	2.24
Aug 2005	166,745,682	5	0.58	2	0.11	0	-----	2	0.26	1	0.05	0	-----	0	-----	1.83
Sep 2005	22,057,409	6	0.88	3	0.03	0	-----	1	0.09	3	<0.01	0	-----	0	-----	1.52
Jun 2006	609,612,839	6	0.98	7	0.01	0	-----	1	<0.01	2	<0.01	1	<0.01	0	-----	0.97
Jul 2006	968,250,327	10	0.98	4	<0.01	1	<0.01	1	<0.01	4	<0.01	1	0.01	1	<0.01	1.43
Aug 2006	2,060,734,486	13	0 95	6	0.02	0	-----	1	0.02	3	<0.01	2	0.01	1	<0.01	1.81
Sep 2006	852,699,287	13	0 95	8	0.03	0	-----	1	0.01	2	<0.01	1	<0.01	1	<0.01	1.82
Jun 2007	1,819,909,690	10	0 91	10	0.07	1	<0.01	1	0.01	2	0.01	0	-----	0	-----	0.67
Jul 2007	800,167,337	10	0.65	8	0.02	0	-----	1	0.04	1	0.15	2	0.15	0	-----	1.49
Aug 2007	1,497,597,364	8	0.91	8	0.02	1	<0.01	0	-----	1	0.02	1	0.03	3	0.01	1.65
Sep 2007	887,246,429	9	0.94	8	0.03	0	-----	1	0.01	3	<0.01	1	0.02	2	<0.01	0.91
May 2008	536,864,521	11	0.98	2	<0.01	2	0.01	1	0.01	1	<0.01	0	-----	1	<0.01	1.72
Jun 2008	591,651,492	11	0.95	8	<0.01	1	<0.01	1	0.04	0	-----	0	-----	1	<0.01	1.52
Jul 2008	249,695	3	0.40	6	0.09	0	-----	1	0.42	3	0.01	2	0.08	0	-----	1 35
Aug 2008	213,733,459	9	0.72	8	0.01	3	0.01	1	0.20	6	0.06	2	<0.01	0	-----	1.75
Sep 2008	172,938,871	7	0.46	7	0.10	1	<0.01	2	0.34	4	0.08	2	0.03	1	<0.01	1.81
Mean*	**703,001,891**	**8.5**	**0.80**	**6.4**	**0.04**	**0.6**	**<0.01**	**1.2**	**0.11**	**2.6**	**0.04**	**0.9**	**0.03**	**0.6**	**<0.01**	**1.54**

* Mean percent composition represents the mean when taxa of that division are present.

Plate 163. Dominant taxa present in phytoplankton grab samples collected at the near-dam monitoring site (site OAHLK1073A) at Oahe Reservoir during the 5-year period 2004 through 2008.

Date	Division	Dominant Taxa*	Percent of Total Biovolume
June 2004	Cyanobacteria	*Anabaena spp.*	0.34
	Pyrrophyta	*Peridinium inconspicuum*	0.30
	Bacillariophyta	*Fragilaria construens*	0.17
	Cryptophyta	*Rhodomonas minuta*	0.14
July 2004	Cryptophyta	*Rhodomonas minuta*	0.59
	Cryptophyta	*Cryptomonas spp.*	0.16
	Bacillariophyta	*Asterionella formossa*	0.12
August 2004	Bacillariophyta	*Fragilaria crotonensis*	0.75
	Pyrrophyta	*Ceratium hirundinella*	0.13
September 2004	Bacillariophyta	*Aulacoseira islandica*	0.25
	Cyanobacteria	*Anabaena circinalis*	0.23
	Bacillariophyta	*Cyclotella spp.*	0.13
	Cyanobacteria	*Anabaena flos-aquae*	0.11
May 2005	Bacillariophyta	*Asterionella formossa*	0.60
	Bacillariophyta	*Fragilaria construens*	0.33
June 2005	Bacillariophyta	*Stephanodiscus spp.*	0.29
	Pyrrophyta	*Peridinium spp.*	0.22
	Bacillariophyta	*Fragilaria crotonensis*	0.14
	Bacillariophyta	*Asterionella formossa*	0.14
	Cryptophyta	*Cryptomonas spp.*	0.11
July 2005	Chrysophyta	*Dinobryon sertularia*	0.35
	Pyrrophyta	*Ceratium hirundinella*	0.25
	Bacillariophyta	*Stephanodiscus hantzschii*	0.20
August 2005	Bacillariophyta	*Asterionella formossa*	0.41
	Bacillariophyta	*Synedra spp.*	0.23
	Bacillariophyta	*Navicula spp.*	0.14
	Chlorophyta	*Chlamydomonas spp.*	0.12
September 2005	Bacillariophyta	*Aulacoseira granulata*	0.22
	Cyanobacteria	*Anabaena spp.*	0.18
	Chrysophyta	*Dinobryon sertularia*	0.13
May 2006	Bacillariophyta	*Fragilaria crotonensis*	0.32
	Bacillariophyta	*Asterionella formossa*	0.26
	Bacillariophyta	*Fragilaria spp.*	0.22
June 2006	Bacillariophyta	*Fragilaria crotonensis*	0.39
	Bacillariophyta	*Asterionella formossa*	0.26
	Chlorophyta	*Cosmarium spp.*	0.17
July 2006	Cryptophyta	*Rhodomonas minuta*	0.29
	Chlorophyta	*Cosmarium spp.*	0.17
	Chlorophyta	*Golenkinia radiata*	0.11
August 2006	Bacillariophyta	*Fragilaria crotonensis*	0.27
	Pyrrophyta	*Ceratium hirundinella*	0.22
	Cryptophyta	*Rhodomonas minuta*	0.11
September 2006	Cyanobacteria	*Anabaena spp.*	0.23
	Pyrrophyta	*Ceratium hirundinella*	0.19
	Chlorophyta	*Cosmarium spp.*	0.19
	Cryptophyta	*Rhodomonas minuta*	0.17

Plate. 163. (Continued)

May 2007	Bacillariophyta	*Stephanodiscus sp.*	0.26
	Bacillariophyta	*Fragilaria capucina*	0.20
	Bacillariophyta	*Cyclotella sp.*	0.13
June 2007	Bacillariophyta	*Fragilaria capucina*	0.72
	Bacillariophyta	*Asterionella formossa*	0.12
July 2007	Bacillariophyta	*Fragilaria capucina*	0.46
	Bacillariophyta	*Tabellaria flocculosa*	0.12
	Cryptophyta	*Rhodomonas sp.*	0.12
	Pyrrophyta	*Ceratium hirundinella*	0.12
August 2007	Cryptophyta	*Rhodomonas sp.*	0.35
	Pyrrophyta	*Ceratium cornutum*	0.19
	Pyrrophyta	*Ceratium hirundinella*	0.16
	Chrysophyta	*Dinobryon sp.*	0.10
September 2007	Pyrrophyta	*Ceratium hirundinella*	0.40
	Bacillariophyta	*Fragilaria capucina*	0.37
	Chrysophyta	*Dinobryon sp.*	0.11
May 2008	Bacillariophyta	*Asterionella formossa*	0.43
	Bacillariophyta	*Tabellaria flocculosa*	0.50
June 2008	Bacillariophyta	*Asterionella formossa*	0.59
	Bacillariophyta	*Tabellaria flocculosa*	0.35
July 2008	Bacillariophyta	*Fragilaria crotonensis*	0.66
	Bacillariophyta	*Tabellaria flocculosa*	0.14
	Chlorophyta	*Chlamydomonas sp.*	0.01
August 2008	Chlorophyta	*Staurastrum sp.*	0.15
	Chrysophyta	*Dinobryon sp.*	0.32
	Cryptophyta	*Rhodomonas sp.*	0.45
September 2008	Bacillariophyta	*Fragilaria sp.*	0.79

* Dominant taxa are genera or species (depending on identification level) that comprised more than 10% of the total sample biovolume.

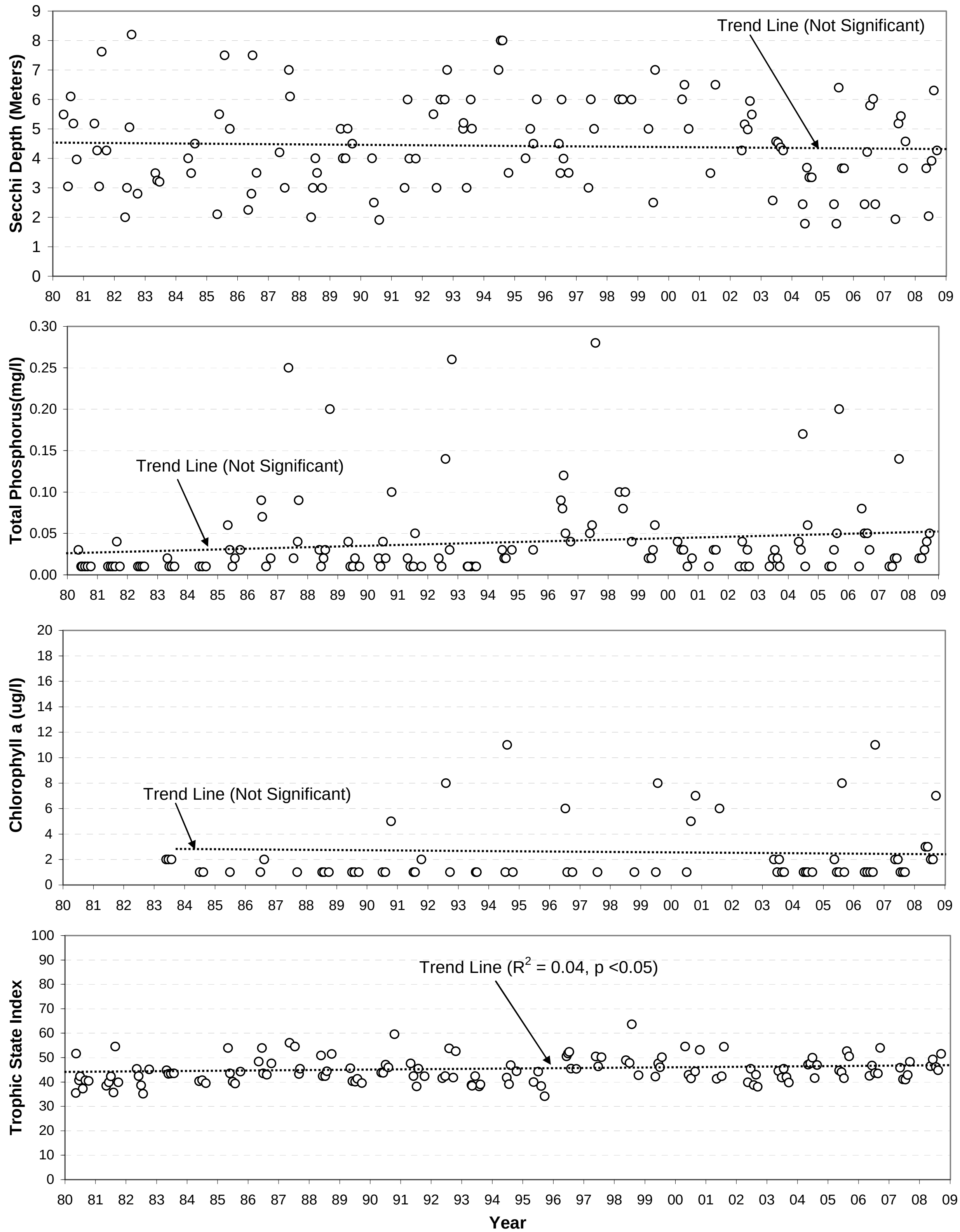


Plate 164. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and Trophic State Index (TSI) monitored in Oahe Reservoir at the near-dam, ambient site (i.e., site OAHLK1073A) over the 29-year period of 1980 through 2008.

Plate 165. Summary of monthly (April through September) water quality conditions monitored in the Missouri River at Bismarck, North Dakota (Site OAHNFMORR1) during the 4-year period 2005 through 2008.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit[(A)]	No. of Obs.	Mean[(B)]	Median	Min.	Max.	State WQS Criteria[(C)]	No. of WQS Exceedences	Percent WQS Exceedence
Stream Flow (cfs)	1	21	15,961	15,525	10,564	26,800	-----	-----	-----
Water Temperature (C)	0.1	21	18.5	18.1	9.9	25.5	29.4[(1)]	0	0%
Dissolved Oxygen (mg/l)	0.1	21	9.3	9.1	8.1	10.6	≥ 5.0[(1)]	0	0%
Dissolved Oxygen (% Sat.)	0.1	21	102.4	102.2	93.6	109.7	-----	-----	-----
pH (S.U.)	0.1	21	8.3	8.3	8.0	8.7	≥7.0 & ≤9.0[(1)]	0	0%
Specific Conductance (umho/cm)	1	21	623	621	581	659	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	21	377	354	282	531	-----	-----	-----
Turbidity (NTU)	1	21	14	6	n.d.	91	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	15	3	3	n.d.	8	-----	-----	-----
Alkalinity, Total (mg/l)	7	21	160	159	140	185	-----	-----	-----
Ammonia, Total (mg/l)	0.02	21	-----	n.d.	n.d.	0.08	4.7 [(1,2,3)], 1.2 [(1,2,4)]	0	0%
Carbon, Total Organic (mg/l)	0.05	20	3.0	3.1	n.d.	5.0	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	17	9	10	2	16	-----	-----	-----
Chloride, Dissolved (mg/l)	1	16	9	10	8	10	100[(1)]	0	0%
Dissolved Solids, Total (mg/l)	5	20	440	421	290	620	-----	-----	-----
Hardness, Total (mg/l)	0.4	3	208	219	179	225	-----	-----	-----
Iron, Total (ug/l)	40	16	501	450	190	1,614	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	21	0.3	0.3	n.d.	0.7	-----	-----	-----
Manganese, Total (ug/l)	2	16	19	16	10	41	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	20	0.06	0.07	n.d.	0.12	1.0[(1)]	0	0%
Phosphorus, Dissolved (mg/l)	0.02	21	-----	0.02	n.d.	0.17	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	21	0.08	0.04	n.d.	0.29	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	21	-----	n.d.	n.d.	0.06	-----	-----	-----
Sulfate (mg/l)	1	20	166	166	141	190	250[(1)]	0	0%
Suspended Solids, Total (mg/l)	4	21	17	15	n.d.	64	-----	-----	-----
Aluminum, Dissolved (ug/l)	25	2	-----	n.d.	n.d.	n.d.	-----	-----	-----
Aluminum, Total (ug/l)	25	2	285	285	200	370	750[(3)]	0	0%
Antimony, Total (ug/l)	0.5	2	-----	n.d.	n.d.	n.d.	5.6[(5)]	0	0%
Arsenic, Total (ug/l)	1	2	-----	n.d.	n.d.	1	340[(3)], 150[(4)], 10[(5)]	0	0%
Barium, Total (ug/l)	5	2	65	65	60	70	1,000	0	0%
Beryllium, Total (ug/l)	2	2	-----	n.d.	n.d.	n.d.	4[(5)]	0	0%
Cadmium, Total (ug/l)	0.2	2	-----	n.d.	n.d.	n.d.	4.4[(3)], 0.5[(4)], 5[(5)]	0	0%
Chromium, Total (ug/l)	10	2	-----	n.d.	n.d.	n.d.	3,246[(3)], 155[(4)], 100[(5)]	0	0%
Copper, Total (ug/l)	2	2	-----	n.d.	n.d.	n.d.	27.5[(3)], 17.2[(4)], 1,000[(5)]	0	0%
Lead, Total (ug/l)	0.5	2	-----	n.d.	n.d.	n.d.	204[(3)], 7.9[(4)], 15[(5)]	0	0%
Mercury, Total (ug/l)	0.02	3	-----	n.d.	n.d.	n.d.	1.7[(3)], 0.012[(4)], 0.05[(5)]	0, b.d., 0	0%, b.d., 0%
Nickel, Total (ug/l)	10	2	-----	n.d.	n.d.	n.d.	861[(3)], 96[(4)], 100[(5)]	0	0%
Selenium, Total (ug/l)	1	2	-----	n.d.	n.d.	n.d.	20[(3)], 5[(4)], 50[(5)]	0	0%
Silver, Total (ug/l)	1	2	-----	n.d.	n.d.	n.d.	13.7[(3)]	0	0%
Thallium, Total (ug/l)	0.5	2	-----	n.d.	n.d.	n.d.	0.24[(5)]	b.d.	b.d.
Zinc, Total (ug/l)	10	2	-----	25	n.d.	50	220[(3,4)], 7,400[(5)]	0	0%
Pesticide Scan (ug/l)[(D)]	0.05	2	-----	n.d.	n.d.	n.d.	-----	-----	-----

n.d. = Not detected. b.d. = Criterion below detection limit.

(A) Detection limits given for the parameters Stream Flow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

(1) Criteria for Class 1 streams.
(2) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
(3) Acute criterion for aquatic life.
(4) Chronic criterion for aquatic life.
(5) Human health criterion for surface waters.

Note: Some of North Dakota's criteria for metals (i e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

(D) The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, cycloate, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, isopropalin, metolachlor, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, phorate, profluralin, prometon, propachlor, propazine, simazine, terbufos, triallate, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

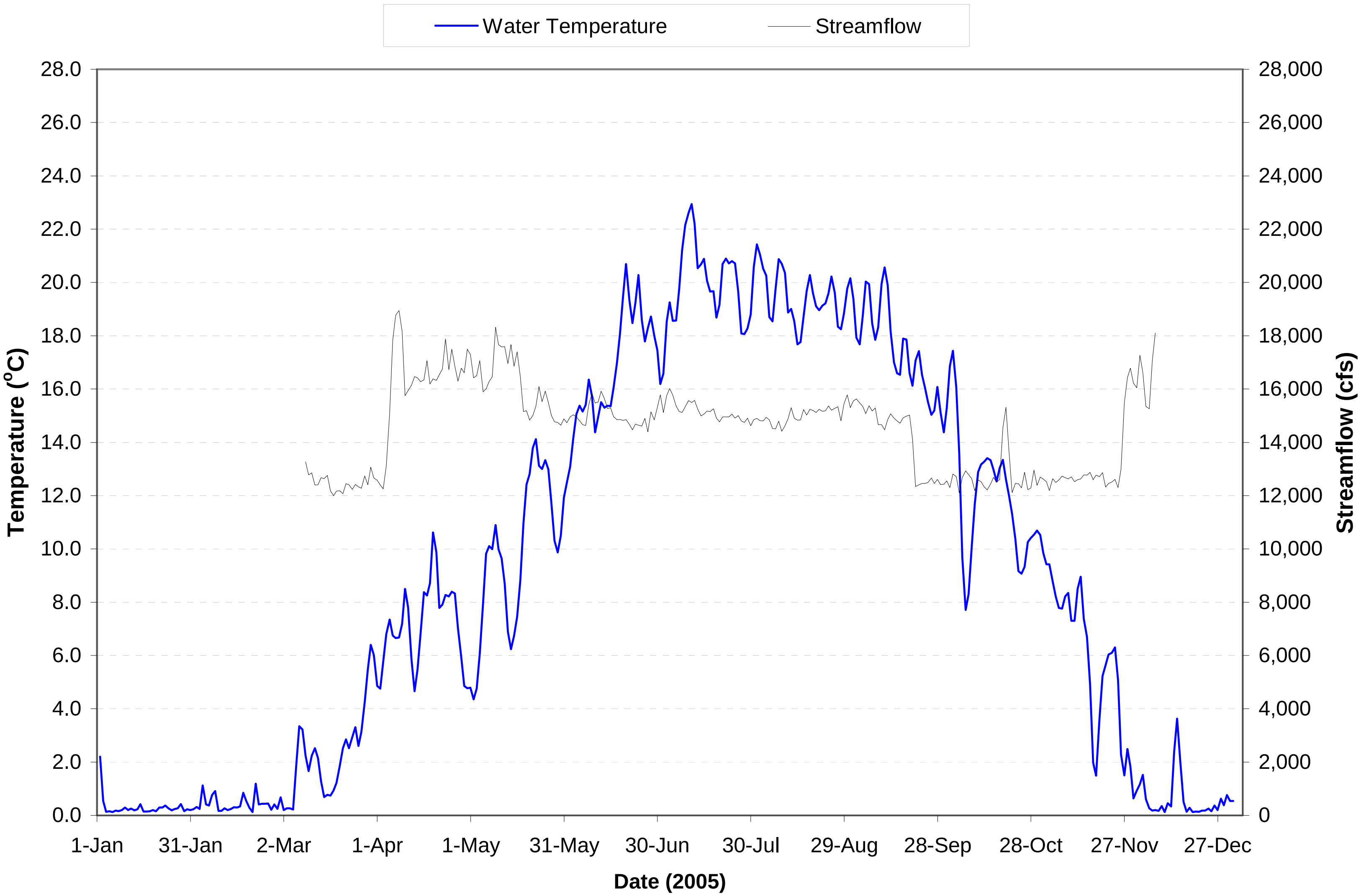


Plate 166. Mean daily water temperature and discharge of the Missouri River near Bismarck, North Dakota (i.e., site OAHNFMORR1) for 2005. Mean daily temperatures and discharges based on hourly measurements recorded on the Missouri River at Bismarck, North Dakota (USGS gaging station 06342500).

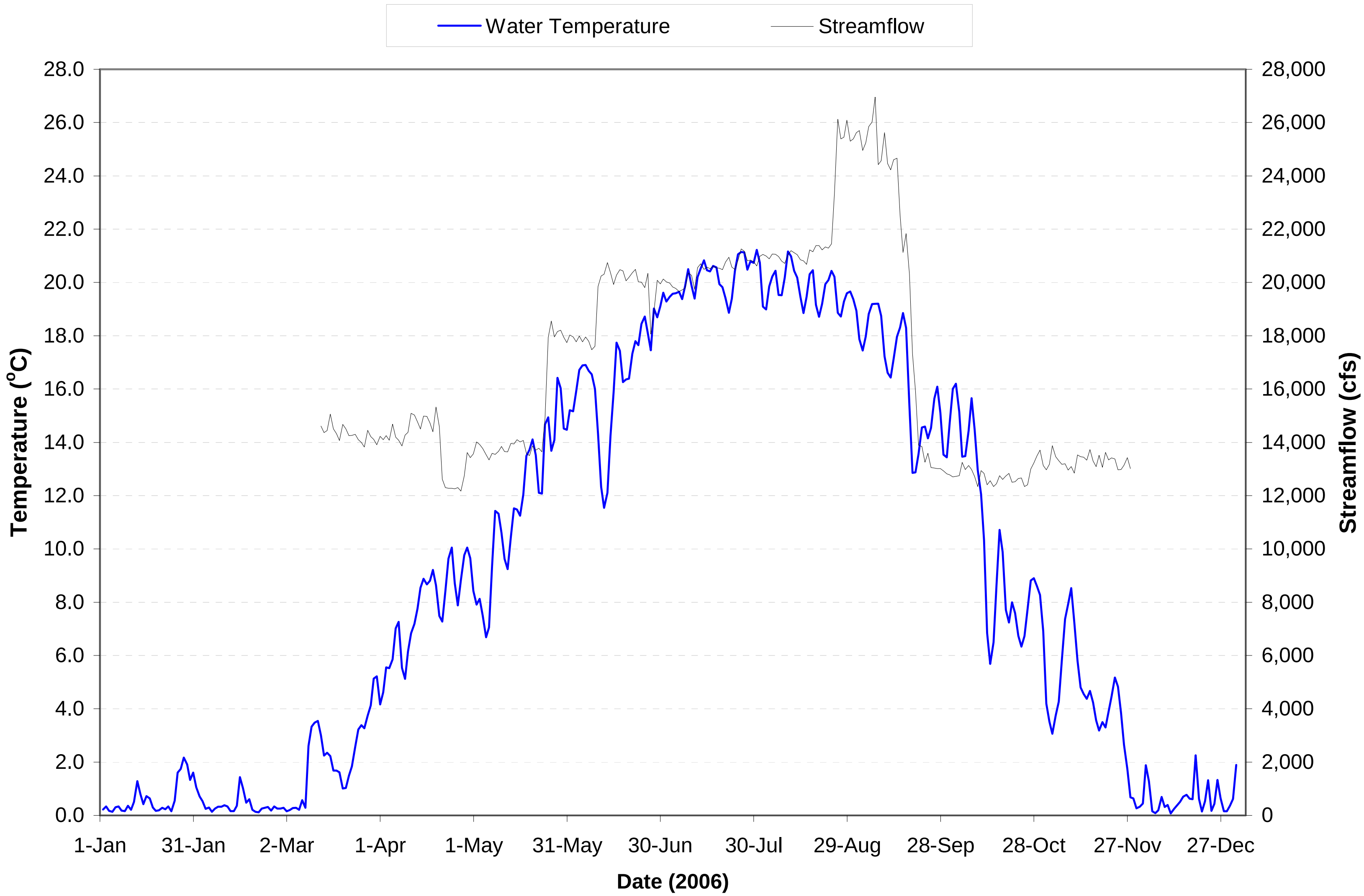


Plate 167. Mean daily water temperature and discharge of the Missouri River near Bismarck, North Dakota (i.e., site OAHNFMORR1) for 2006. Mean daily temperatures and discharges based on hourly measurements recorded on the Missouri River at Bismarck, North Dakota (USGS gaging station 06342500).

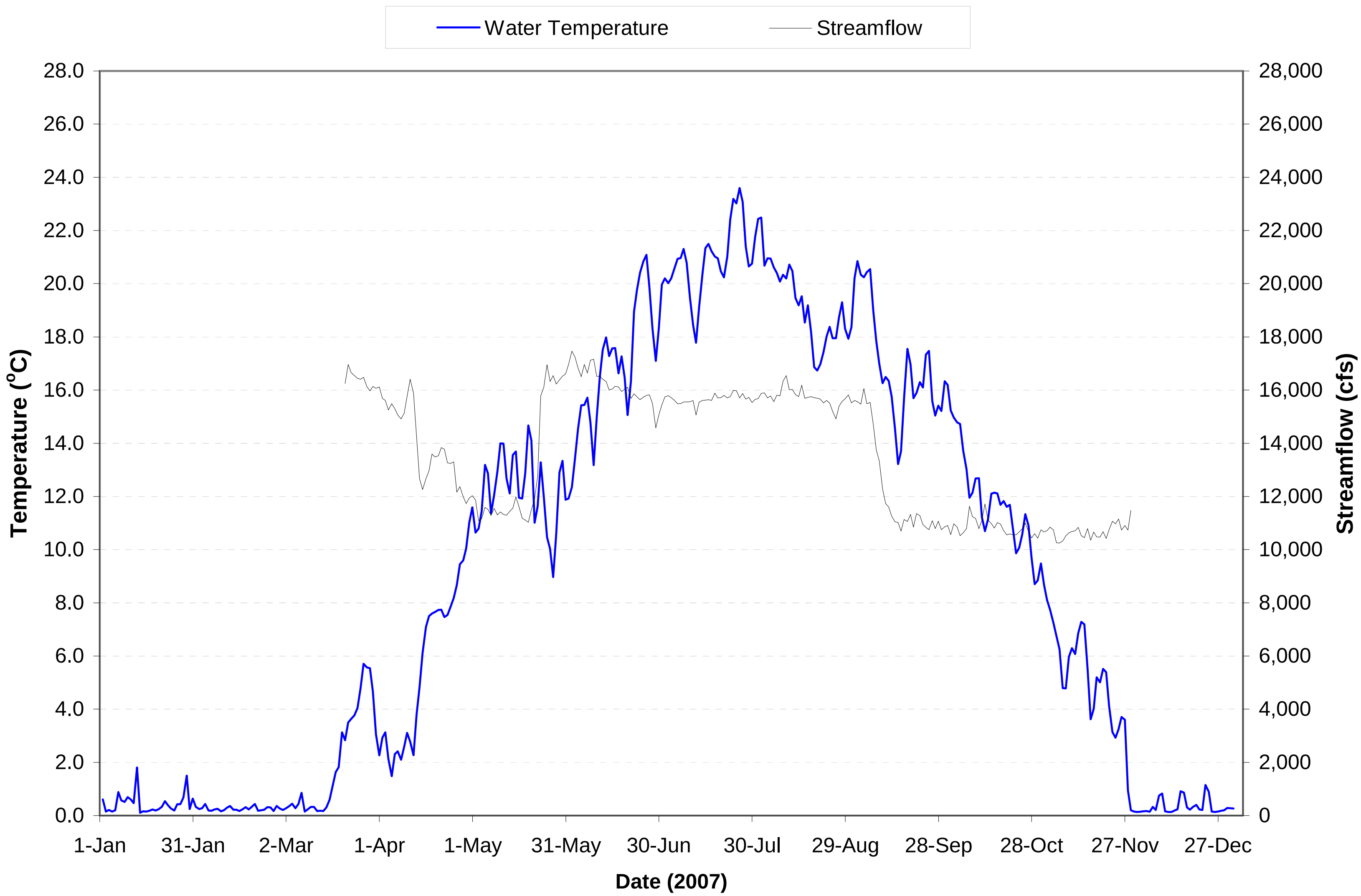


Plate 168. Mean daily water temperature and discharge of the Missouri River near Bismarck, North Dakota (i.e., site OAHNFMORR1) for 2007. Mean daily temperatures and discharges based on hourly measurements recorded on the Missouri River at Bismarck, North Dakota (USGS gaging station 06342500).

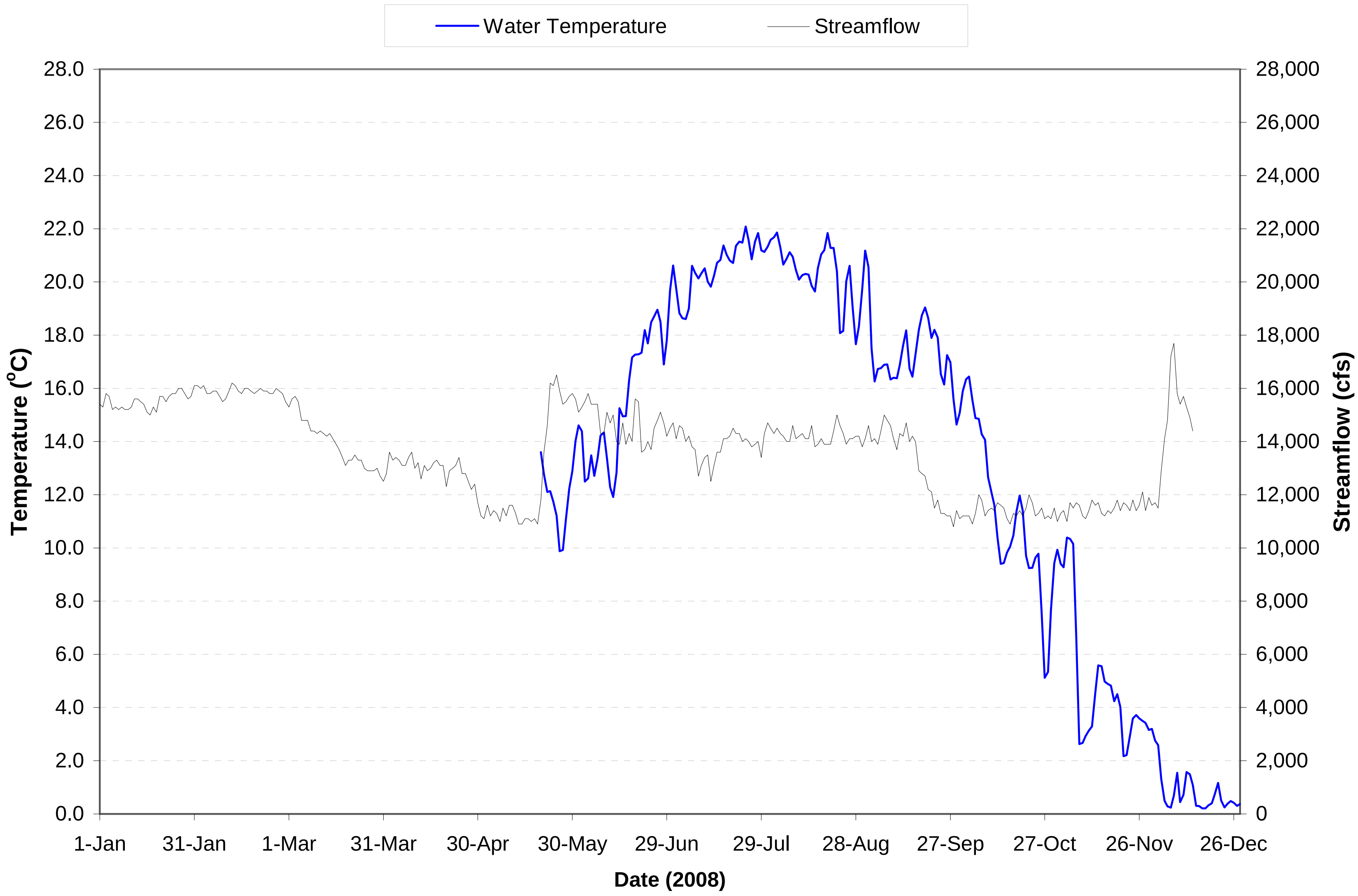


Plate 169. Mean daily water temperature and discharge of the Missouri River near Bismarck, North Dakota (i.e., site OAHNFMORR1) for 2008. Mean daily temperatures and discharges based on hourly measurements recorded on the Missouri River at Bismarck, North Dakota (USGS gaging station 06342500).

Plate 170. Summary of water quality conditions monitored on water discharged through Oahe Dam (i.e., site OAHPP1) during the 5-year period of 2004 through 2008.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit[A]	**No. of Obs.**	**Mean[B]**	**Median**	**Min.**	**Max.**	**State WQS Criteria[C]**	**No. of WQS Exceedences**	**Percent WQS Exceedence**
Dam Discharge (cfs)	1	48	19,765	18,439	0	48,097	-----	-----	-----
Water Temperature (C)	0.1	44	11.9	11.4	1.5	23.2	18.3[1,5]	12	27%
Dissolved Oxygen (mg/l)	0.1	44	10.0	10.0	7.1	13.6	6[1,6,8], 7[1,6,8]	0	0%
Dissolved Oxygen (% Sat.)	0.1	44	95.1	96.1	80.8	105.7	-----	-----	-----
pH (S.U.)	0.1	35	8.3	8.3	7.9	8.7	6 5[1,2,6], 9.0[1,2,5], 9 5[4,5]	0	0%
Specific Conductance (umho/cm)	1	44	662	683	357	816	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	25	385	371	266	541	-----	-----	-----
Turbidity (NTU)	1	22	2	1	n.d.	9	-----	-----	-----
Alkalinity, Total (mg/l)	7	48	170	170	140	205	-----	-----	-----
Ammonia, Total (mg/l)	0.02	48	-----	0.04	n.d.	0 31	3.1 [1,5,9], 1.4 [1,7,9]	0	0%
Carbon, Total Organic (mg/l)	0.05	46	3.0	3.0	1.2	4.3	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	31	8	7	n.d.	19	-----	-----	-----
Chloride, Dissolved (mg/l)	1	29	11	11	9	22	175[1,5], 438[2,5] 100[1,7], 250[2,7]	0	0%
Dissolved Solids, Total (mg/l)	5	48	465	460	396	615	1,750[2,5], 3,500[4,5] 1,000[2,7], 2,000[4,7]	0	0%
Hardness, Total (mg/l)	0.4	3	219	213	209	235	-----	-----	-----
Iron, Total (ug/l)	40	31	162	70	n.d.	763	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	48	0.4	0.4	n.d.	1.8	-----	-----	-----
Manganese, Total (ug/l)	2	31	24	11	n.d.	110	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	48	-----	n.d.	n.d.	0.09	10[2,5]	0	0%
Phosphorus, Dissolved (mg/l)	0.02	33	-----	n.d.	n.d.	0 20	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	48	-----	0.03	n.d.	0.05	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	47	-----	n.d.	n.d.	0.03	-----	-----	-----
Sulfate (mg/l)	1	48	195	195	163	230	875[2,5], 500[2,7]	0	0%
Suspended Solids, Total (mg/l)	4	48	-----	n.d.	n.d.	91	53[1,5], 30[1,7]	1, 3	2%, 6%
Aluminum, Dissolved (ug/l)	25	3	-----	n.d.	n.d.	n.d.	-----	-----	-----
Antimony, Dissolved (ug/l)	0.5	2	-----	n.d.	n.d.	0.6.	5.6[12]	0	0%
Arsenic, Dissolved (ug/l)	1	2	2	2	1	2	340[10], 150[11], 0.018[12]	0, 0, 2	0%, 0%, 100%
Barium, Dissolved (ug/l)	5	2	42	42	41	43	-----	-----	-----
Beryllium, Dissolved (ug/l)	2	4	-----	n.d.	n.d.	n.d.	4[12]	0	0%
Cadmium, Dissolved (ug/l)	0.2	7	-----	n.d.	n.d.	n.d.	4.3[10], 0.42[11], 5[12]	0	0%
Chromium, Dissolved (ug/l)	10	7	-----	n.d.	n.d.	n.d.	1,075[10], 140[11]	0	0%
Copper, Dissolved (ug/l)	2	7	-----	2	n.d.	6	28[10], 17[11], 1,300[12]	0	0%
Lead, Dissolved (ug/l)	0.5	7	-----	n.d.	n.d.	n.d.	148[10], 5.8[11]	0	0%
Mercury, Dissolved (ug/l)	0.02	7	-----	n.d.	n.d.	n.d.	1.7[10], 0.05[12]	0	0%
Mercury, Total (ug/l)	0.02	7	-----	n.d.	n.d.	n.d.	0.77[11]	0	0%
Nickel, Dissolved (ug/l)	10	7	-----	n.d.	n.d.	n.d.	902[10], 100[11], 610[12]	0	0%
Selenium, Total (ug/l)	1	7	-----	n.d.	n.d.	n.d.	-----	-----	-----
Silver, Dissolved (ug/l)	1	7	-----	n.d.	n.d.	n.d.	12[10]	0	0%
Thallium, Total (ug/l)	0.5	2	-----	n.d.	n.d.	n.d.	0.24[12]	b.d.	b.d.
Zinc, Total (ug/l)	10	7	-----	n.d.	n.d.	11	226[10,11], 7,400[12]	0	0%
Pesticide Scan (ug/l)[D]	0.05	5	-----	n.d.	n.d.	n.d.	-----	-----	-----

n.d. = Not detected, b.d. = Criterion below detection limit.

[A] Detection limits given for the parameters Stream Flow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

[B] Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

[C] Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

(1) Criteria for the protection of coldwater permanent fish life propagation waters.
(2) Criteria for the protection of domestic water supply waters.
(3) Criteria for the protection of immersion and limited contact recreation waters (applies only to epilimnion and metalimnion if water body stratified).
(4) Criteria for the protection of commerce and industry waters.
(5) Daily maximum criterion (monitoring results directly comparable to criterion).
(6) Daily minimum criterion (monitoring results directly comparable to criterion).
(7) 30-day average criterion (monitoring results not directly comparable to criterion).
(8) The 7.0 mg/l criterion applies to spawning areas during spawning season, and the 6.0 mg/l criterion applies otherwise.
(9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
(10) Acute (CMC) criterion for the protection of freshwater aquatic life.
(11) Chronic (CCC) criterion for the protection of freshwater aquatic life.
(12) Criterion for the protection of human health.

Note: Some of South Dakota's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

[D] The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, cycloate, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, isopropalin, metolachlor, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, phorate, profluralin, prometon, propachlor, propazine, simazine, terbufos, triallate, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

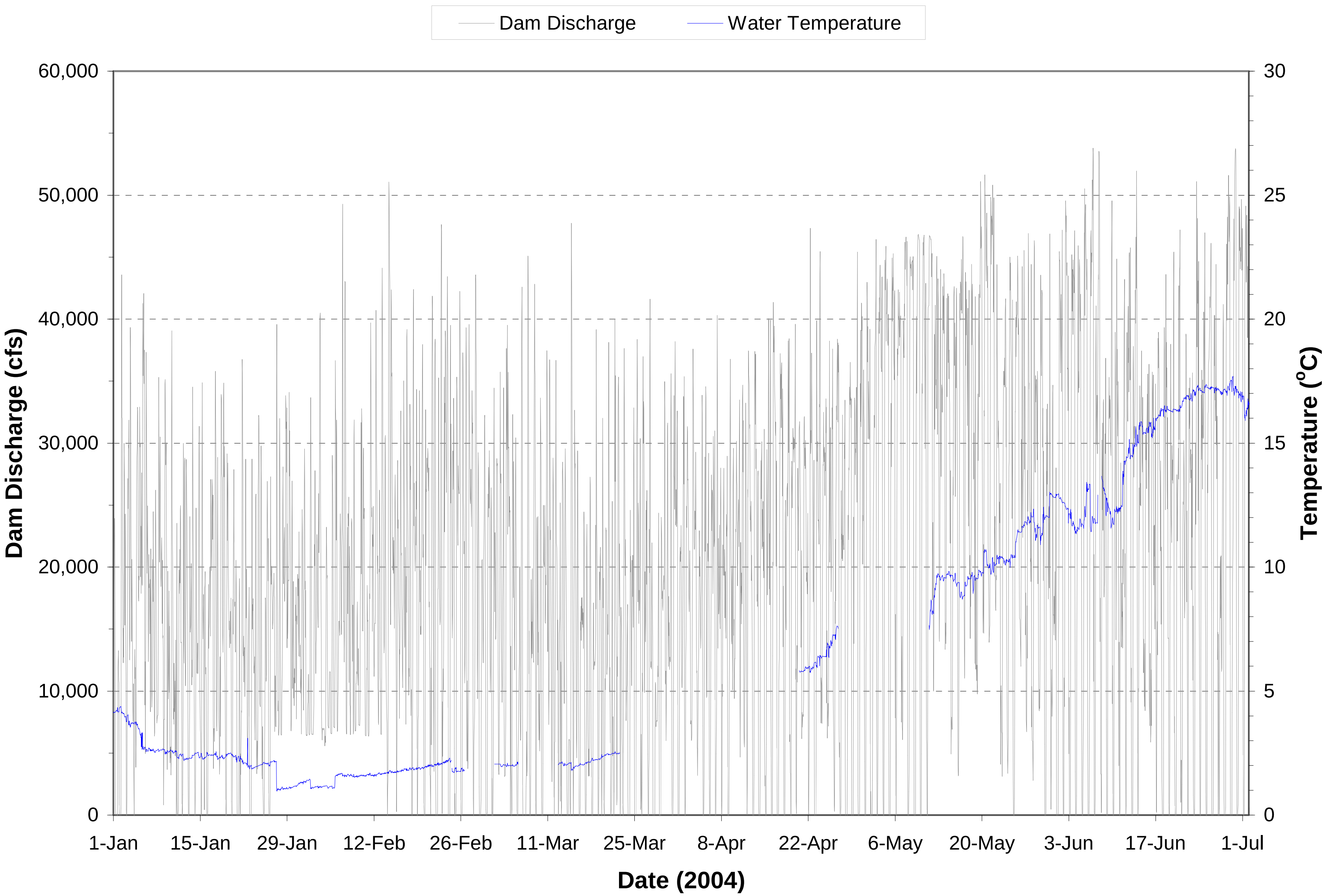


Plate 171. Hourly discharge and water temperature monitored at the Oahe powerplant on water discharged through the dam during the period January through June 2004.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

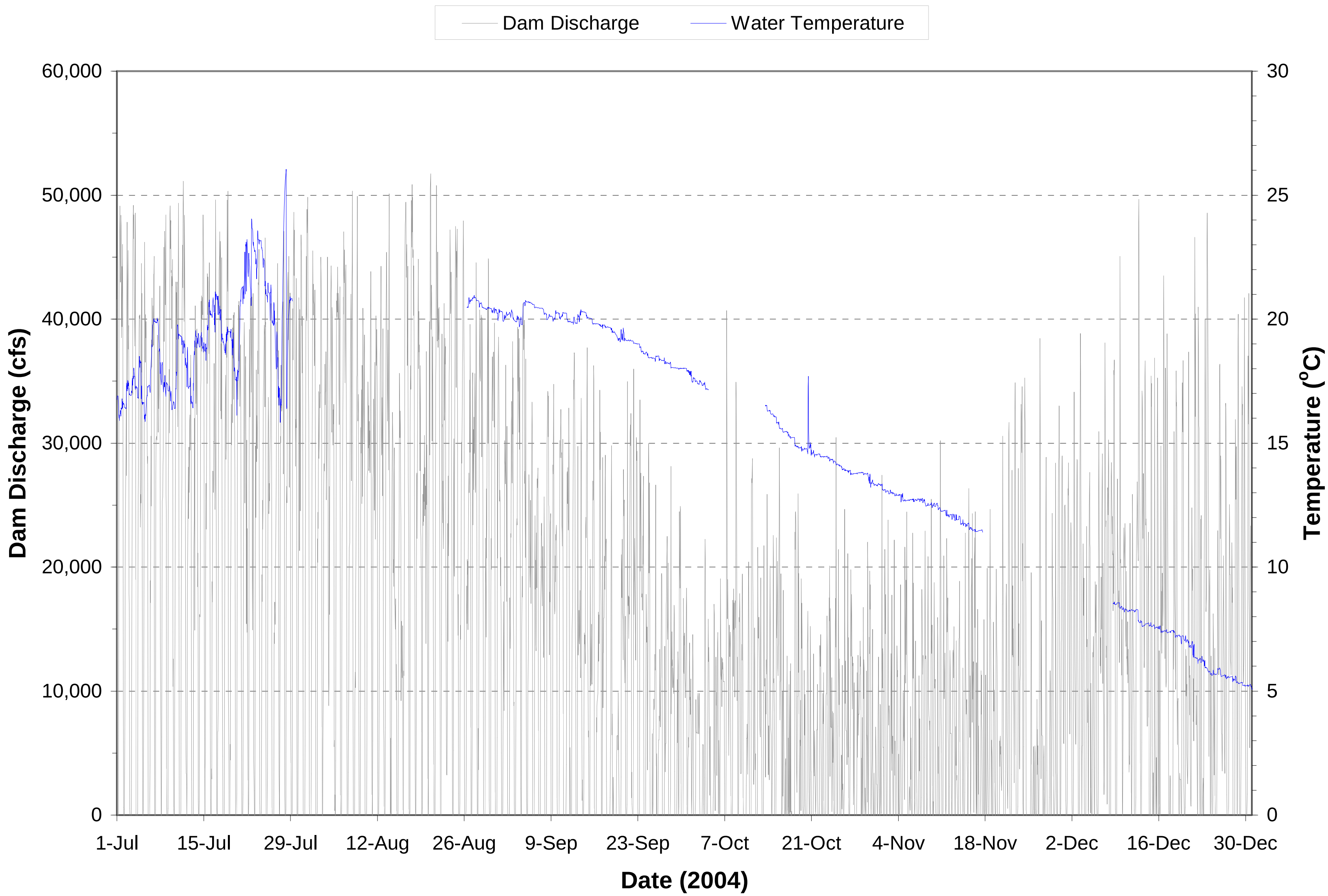


Plate 172. Hourly discharge and water temperature monitored at the Oahe powerplant on water discharged through the dam during the period July through December 2004.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

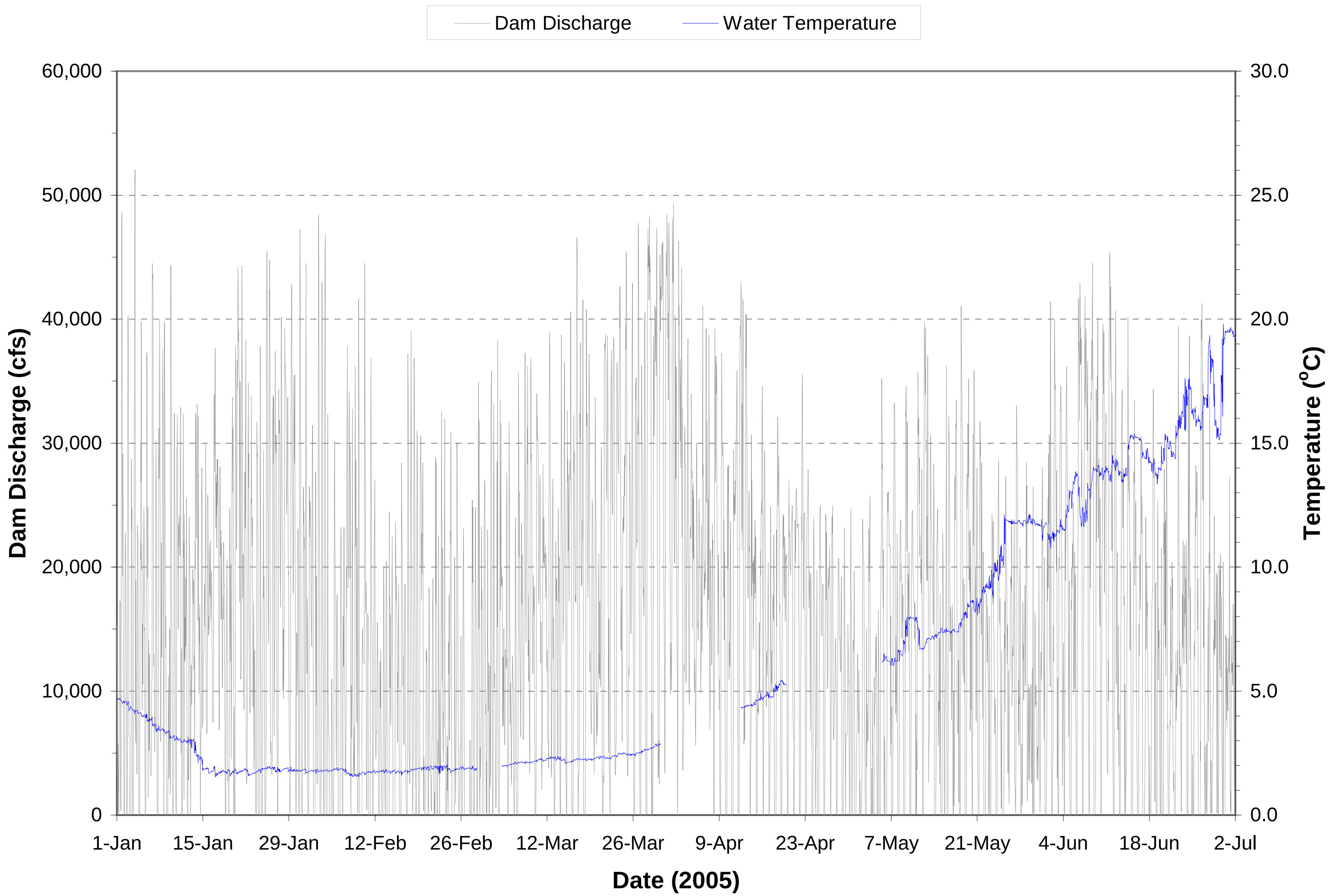


Plate 173. Hourly discharge and water temperature monitored at the Oahe powerplant on water discharged through the dam during the period January through June 2005.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

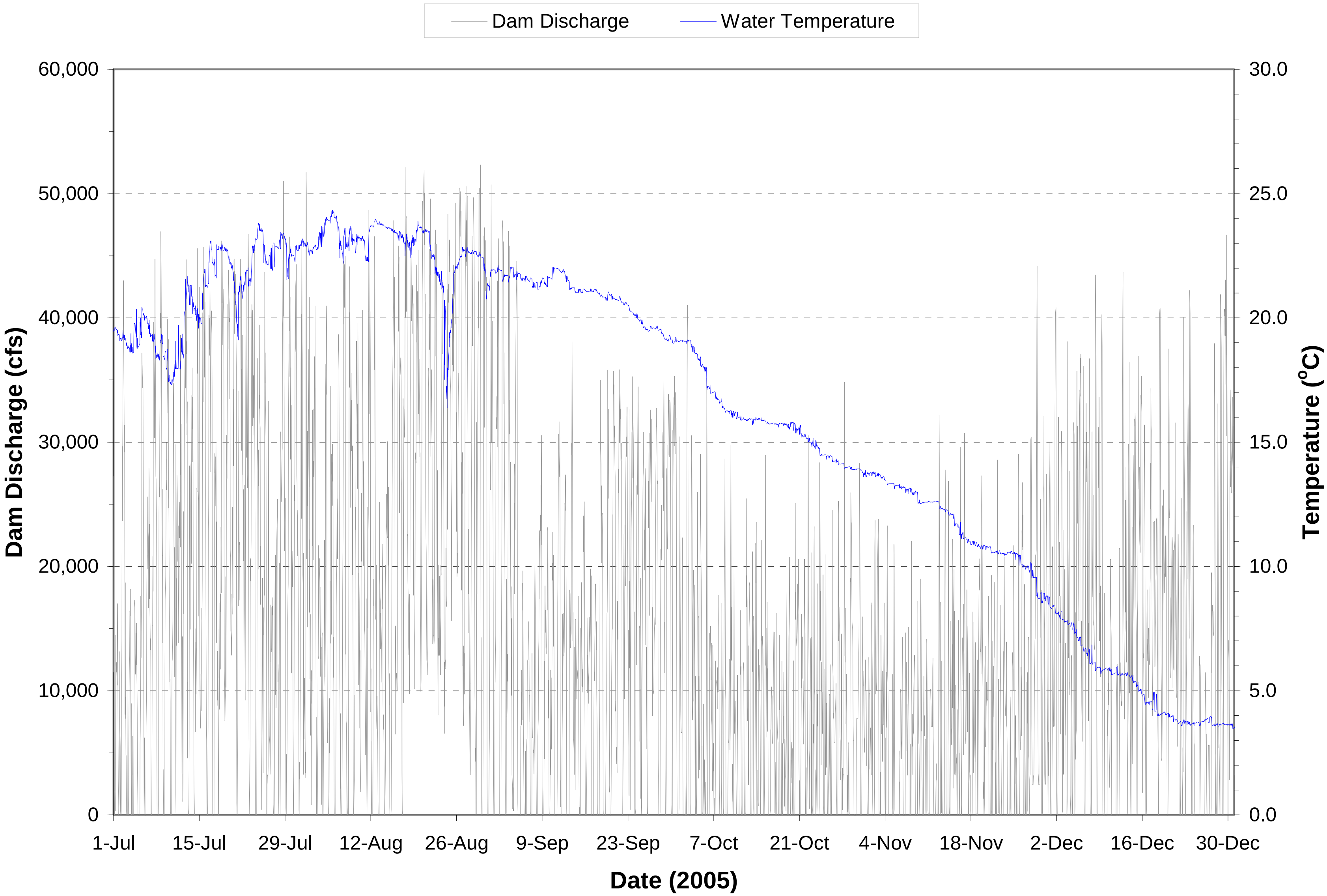


Plate 174. Hourly discharge and water temperature monitored at the Oahe powerplant on water discharged through the dam during the period July through December 2005.

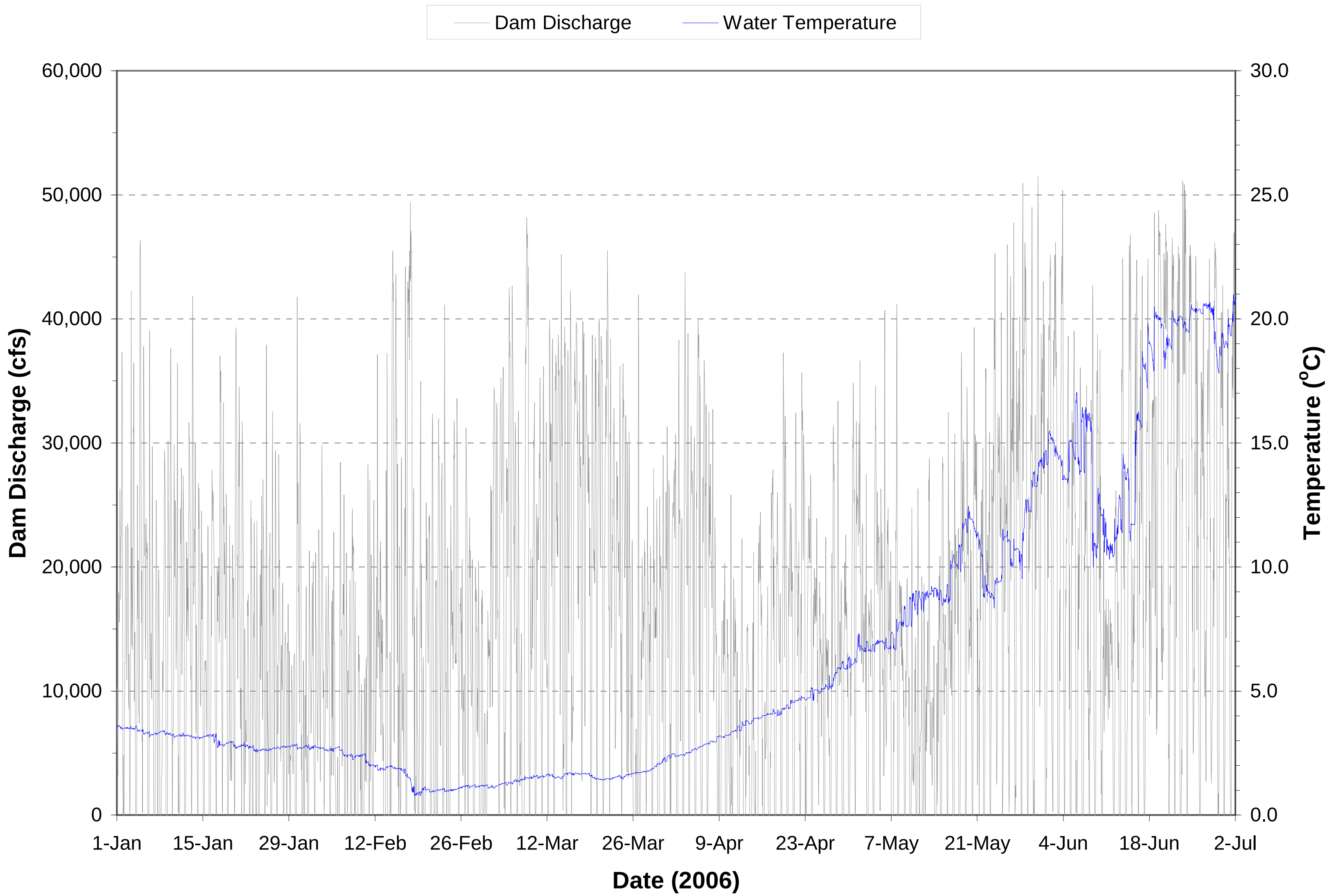


Plate 175. Hourly discharge and water temperature monitored at the Oahe powerplant on water discharged through the dam during the period January through June 2006.

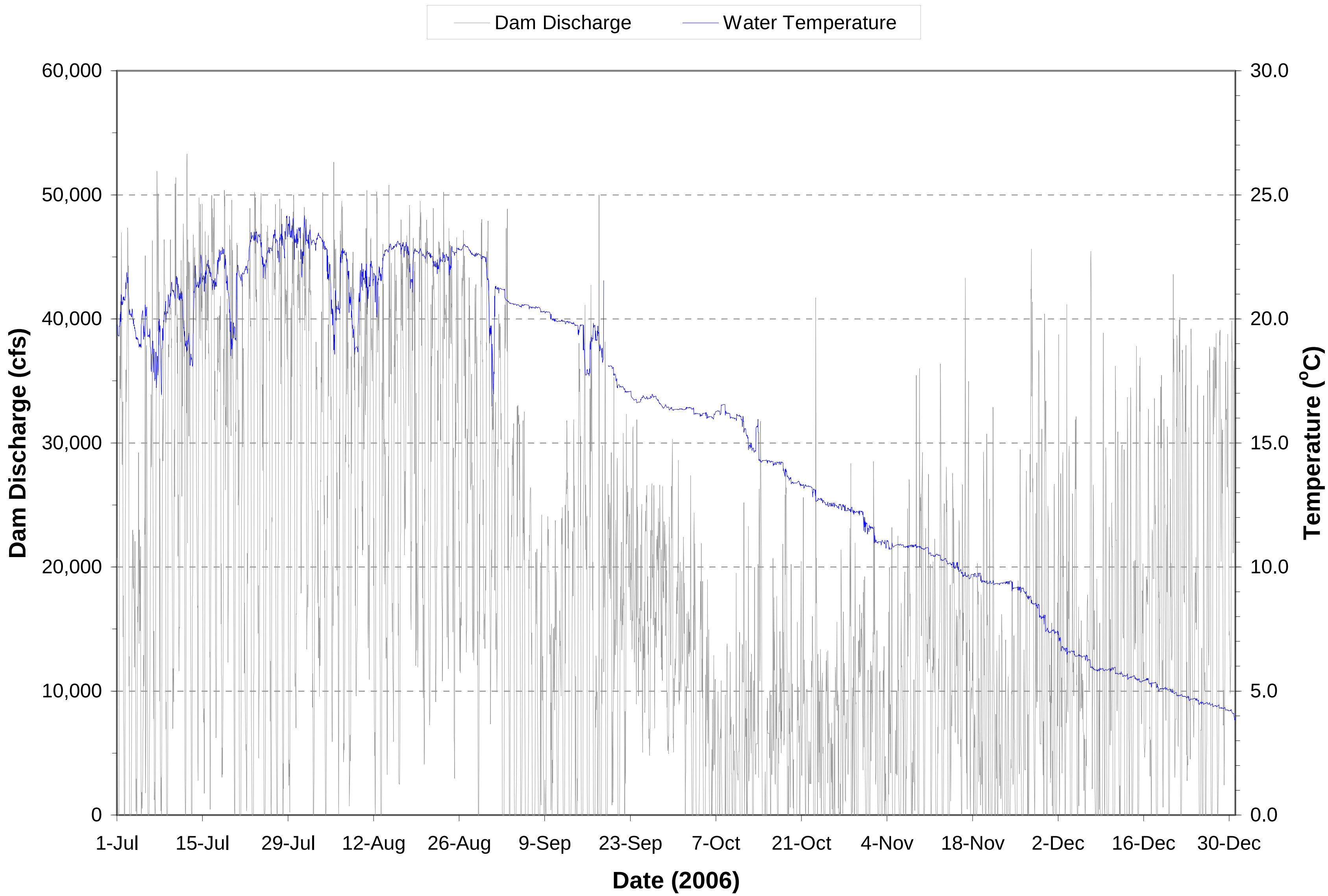


Plate 176. Hourly discharge and water temperature monitored at the Oahe powerplant on water discharged through the dam during the period July through December 2006.

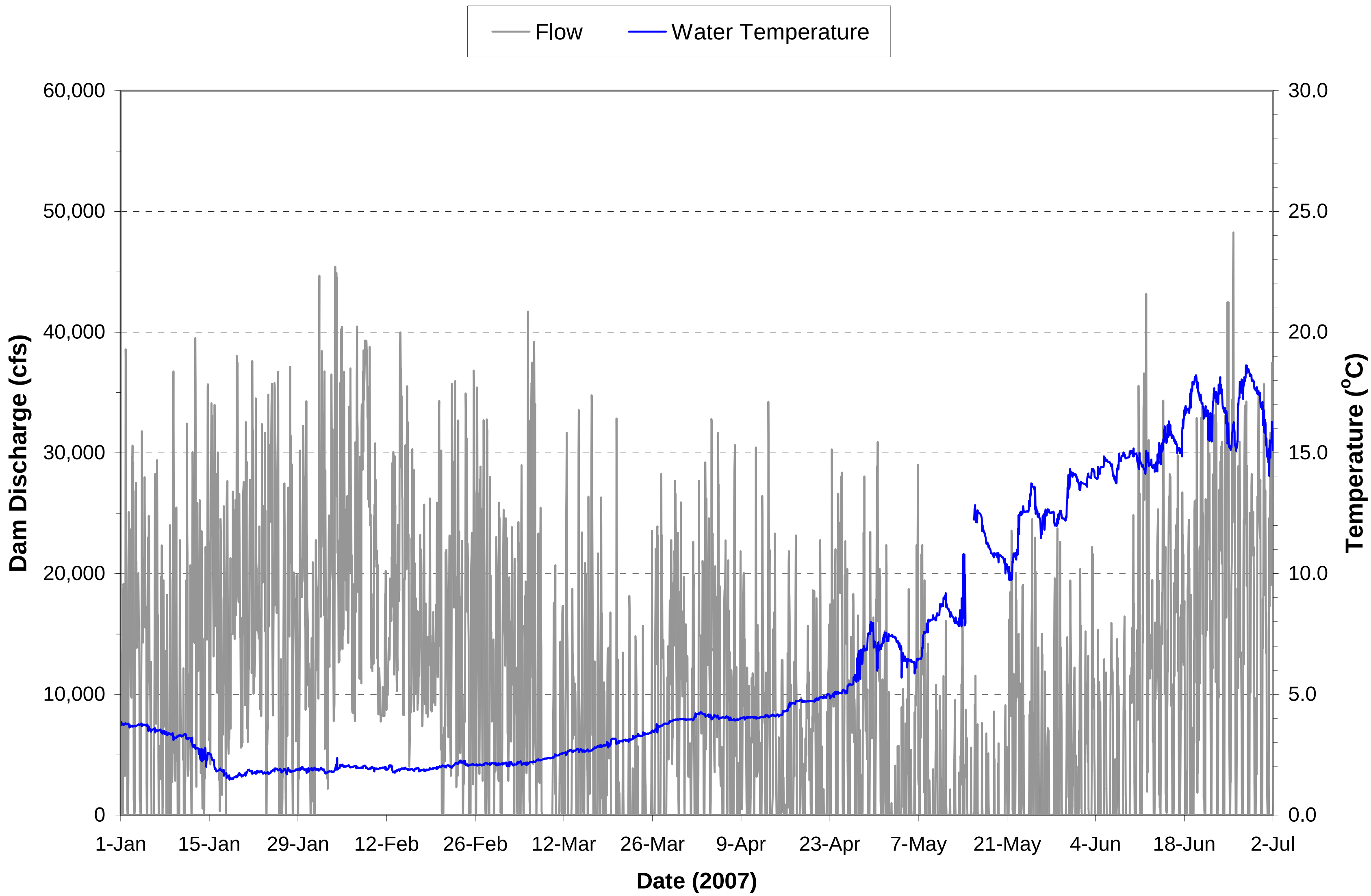


Plate 177. Hourly discharge and water temperature monitored at the Oahe powerplant on water discharged through the dam during the period January through June 2007.

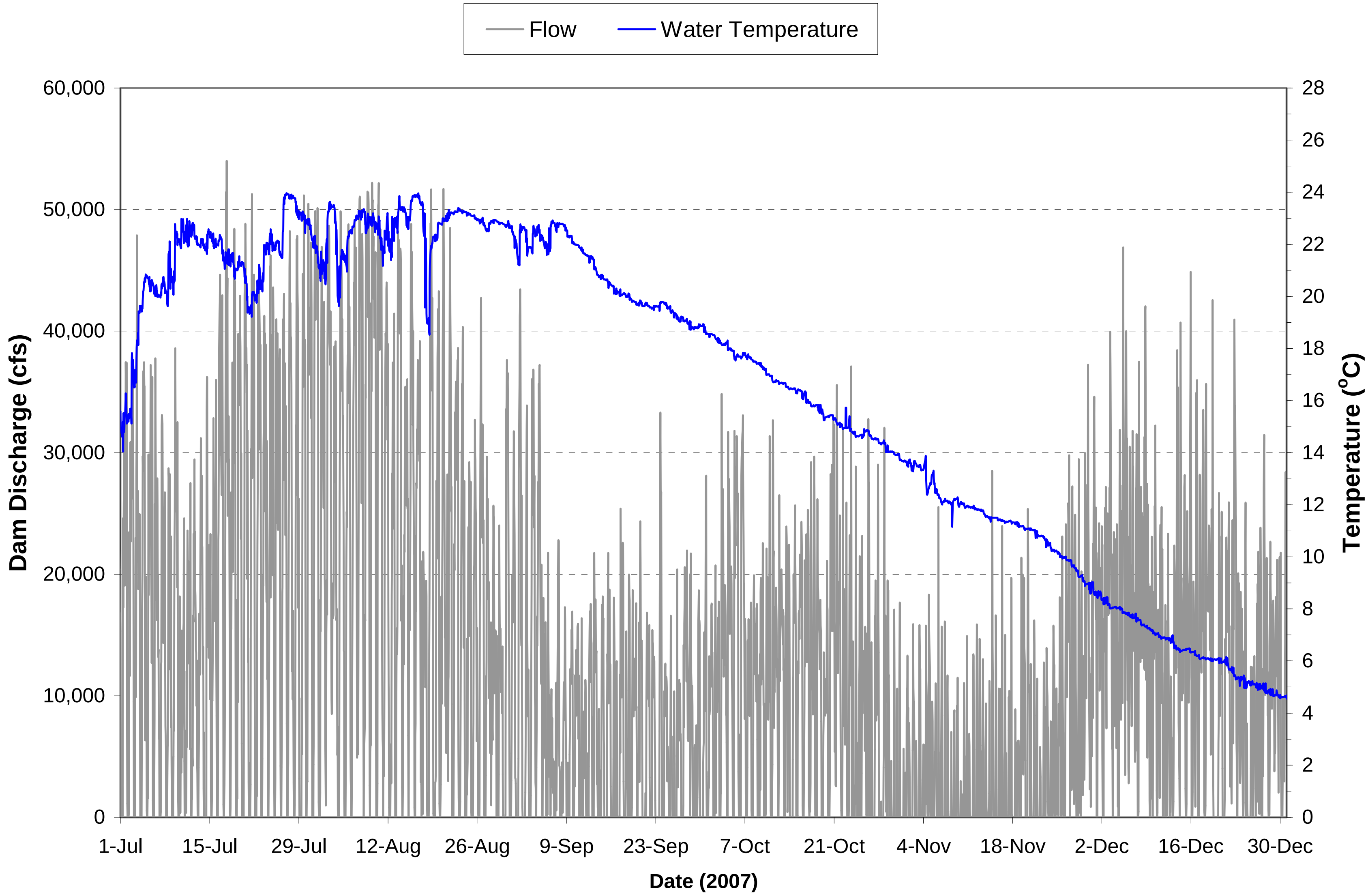


Plate 178. Hourly discharge and water temperature monitored at the Oahe powerplant on water discharged through the dam during the period July through December 2007.

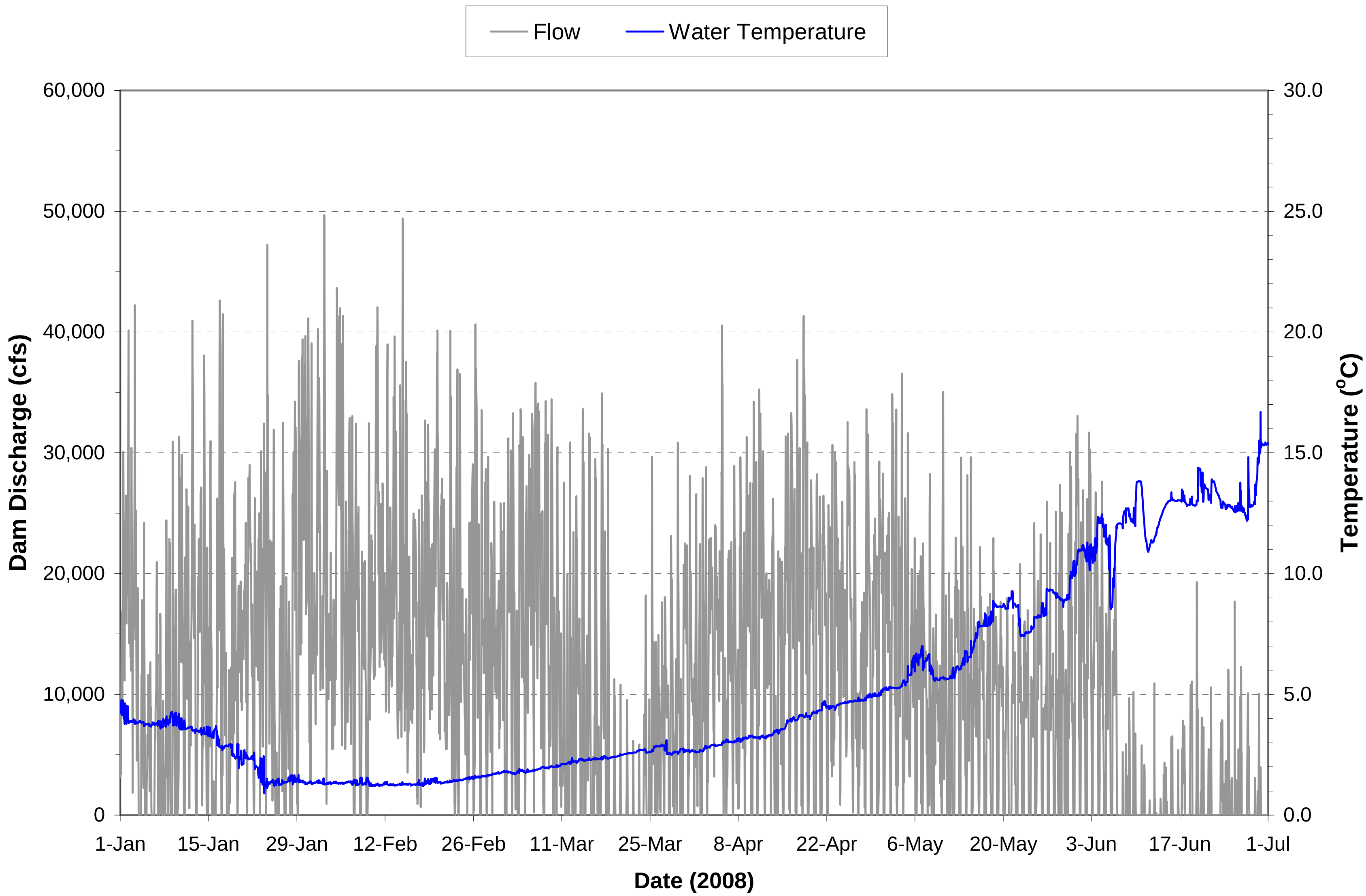


Plate 179. Hourly discharge and water temperature monitored at the Oahe powerplant on water discharged through the dam during the period January through June 2008.

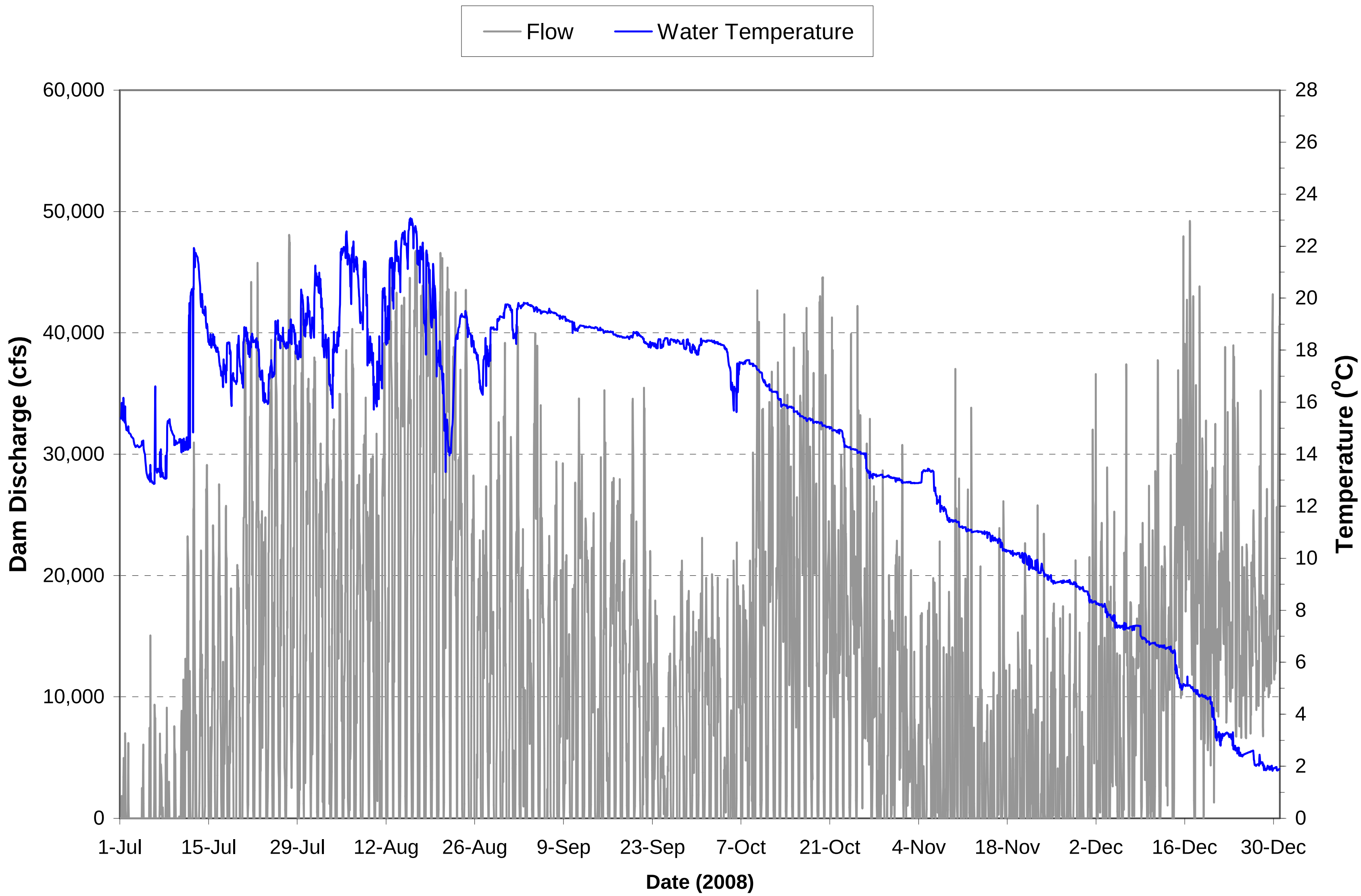


Plate 180. Hourly discharge and water temperature monitored at the Oahe powerplant on water discharged through the dam during the period July through December 2008.

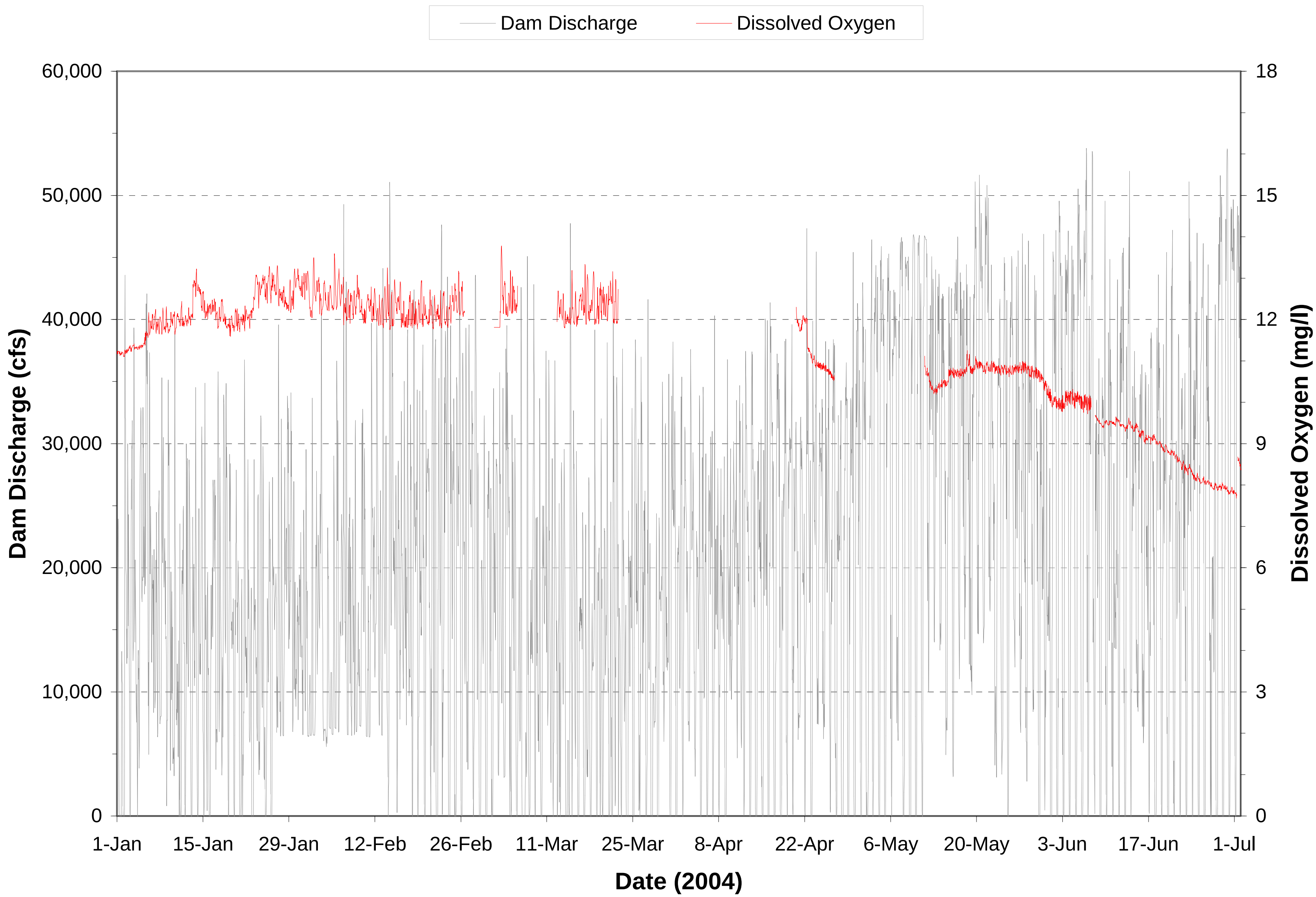


Plate 181. Hourly discharge and dissolved oxygen monitored at the Oahe powerplant on water discharged through the dam during the period January through June 2004.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

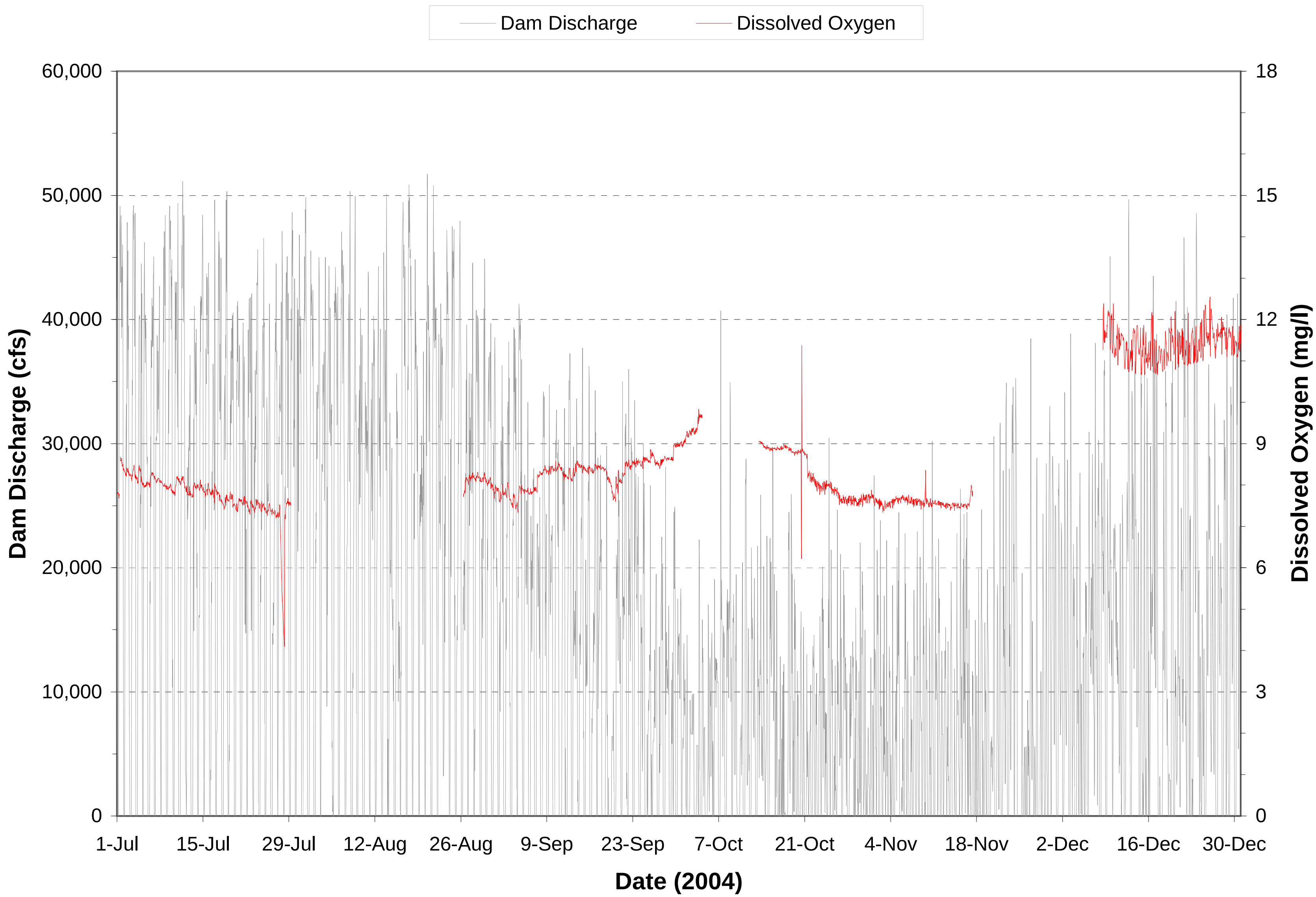


Plate 182. Hourly discharge and dissolved oxygen monitored at the Oahe powerplant on water discharged through the dam during the period July through December 2004.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

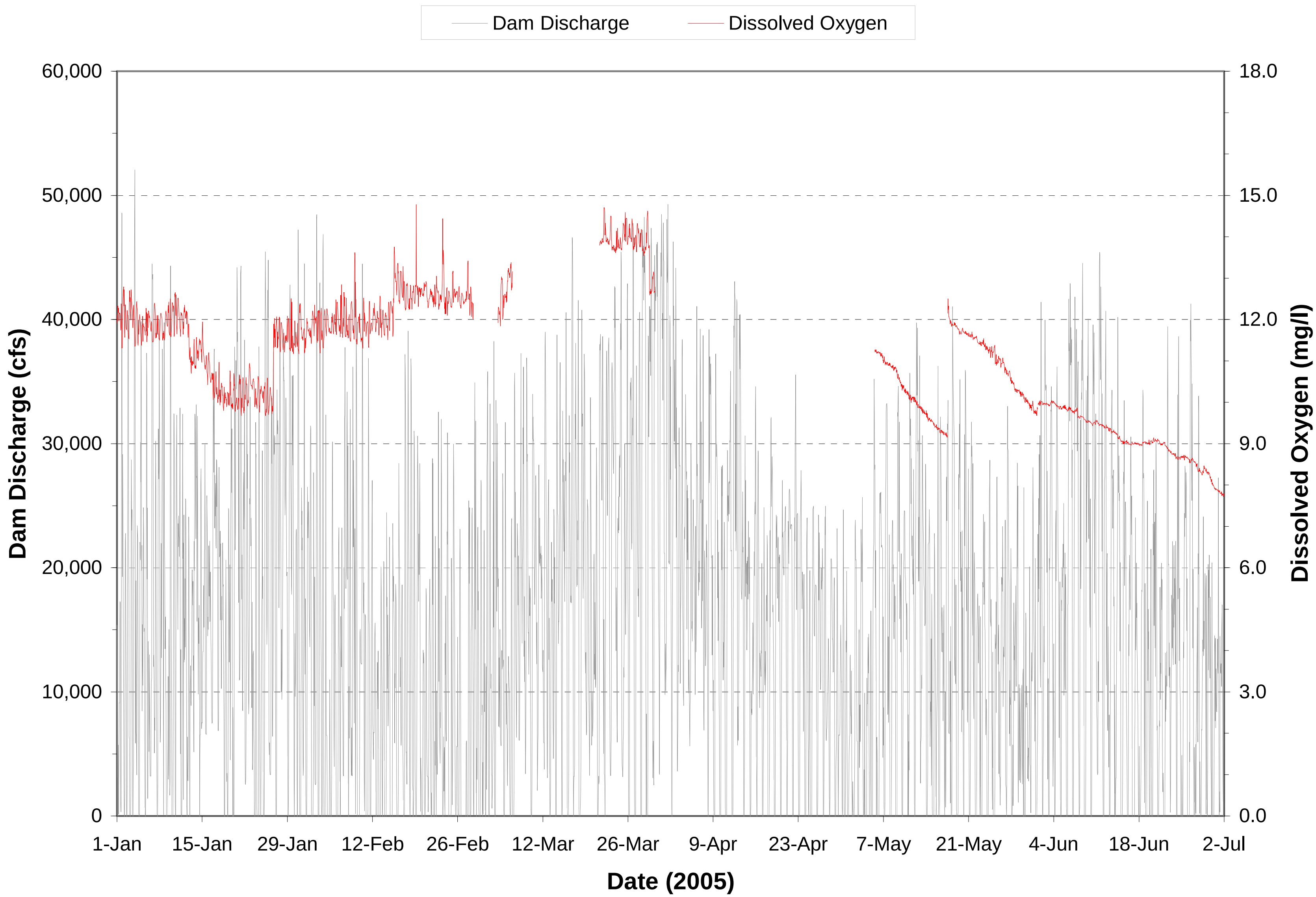


Plate 183. Hourly discharge and dissolved oxygen monitored at the Oahe powerplant on water discharged through the dam during the period January through June 2005.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

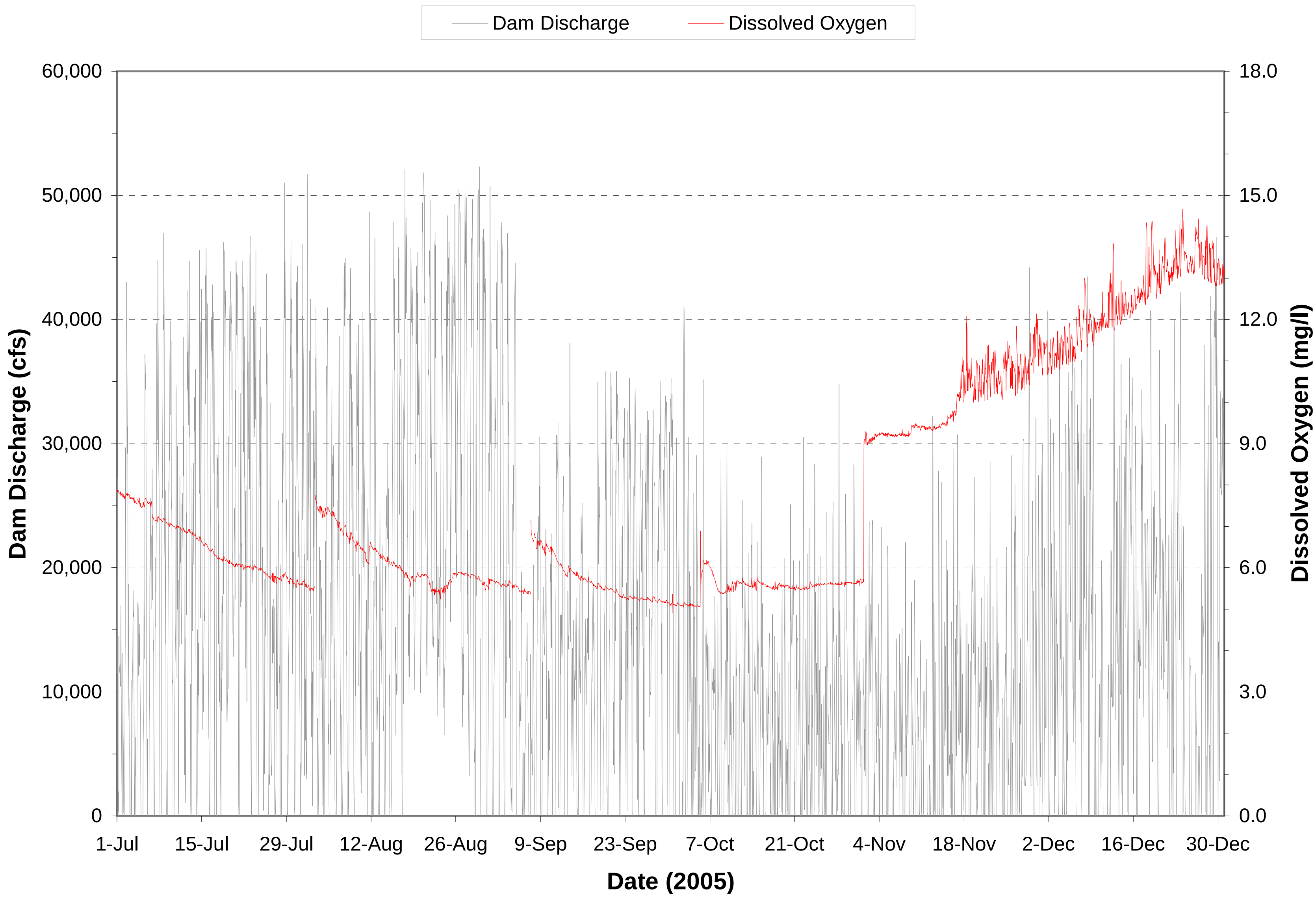


Plate 184. Hourly discharge and dissolved oxygen monitored at the Oahe powerplant on water discharged through the dam during the period July through December 2005.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

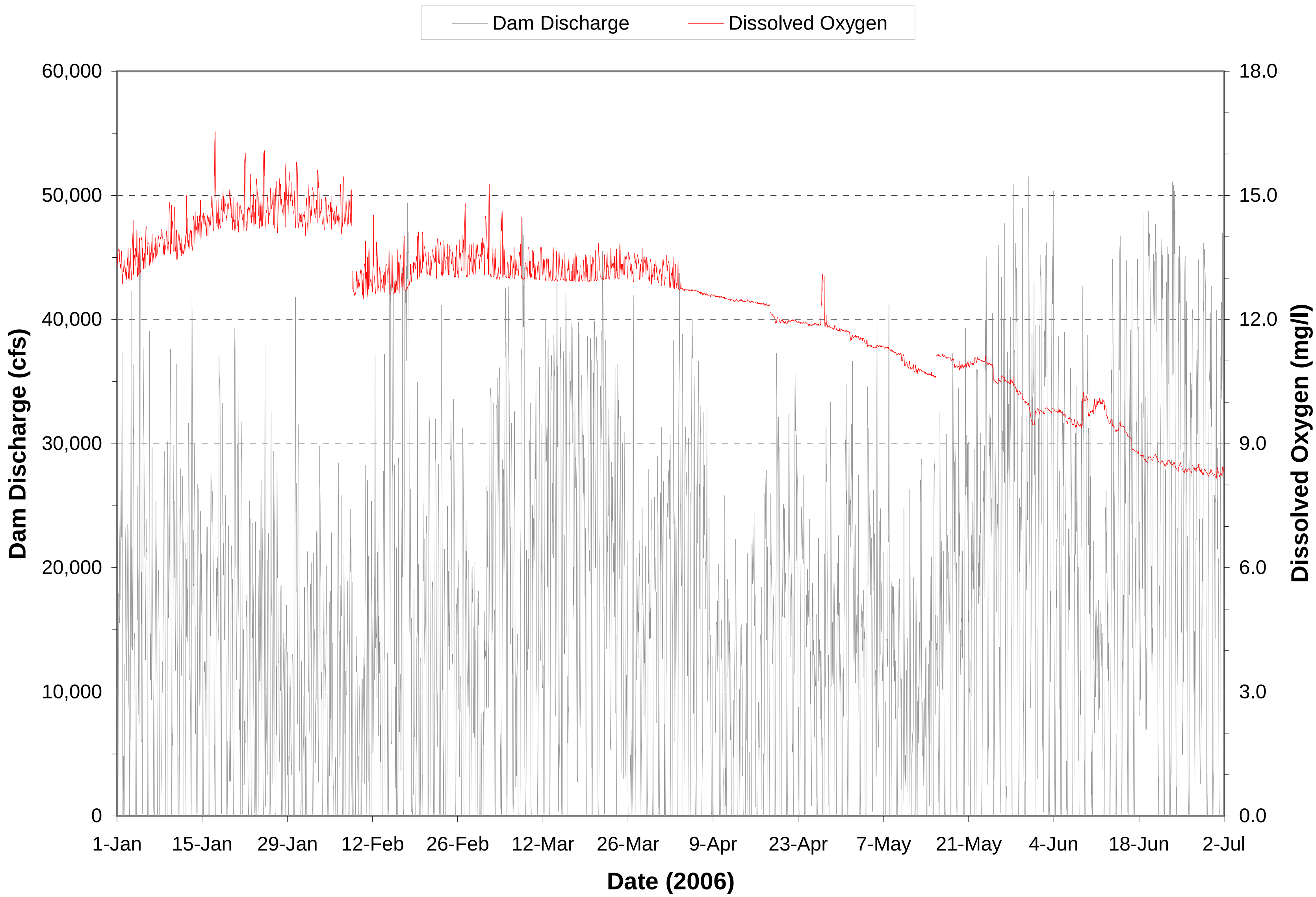


Plate 185. Hourly discharge and dissolved oxygen monitored at the Oahe powerplant on water discharged through the dam during the period January through June 2006.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

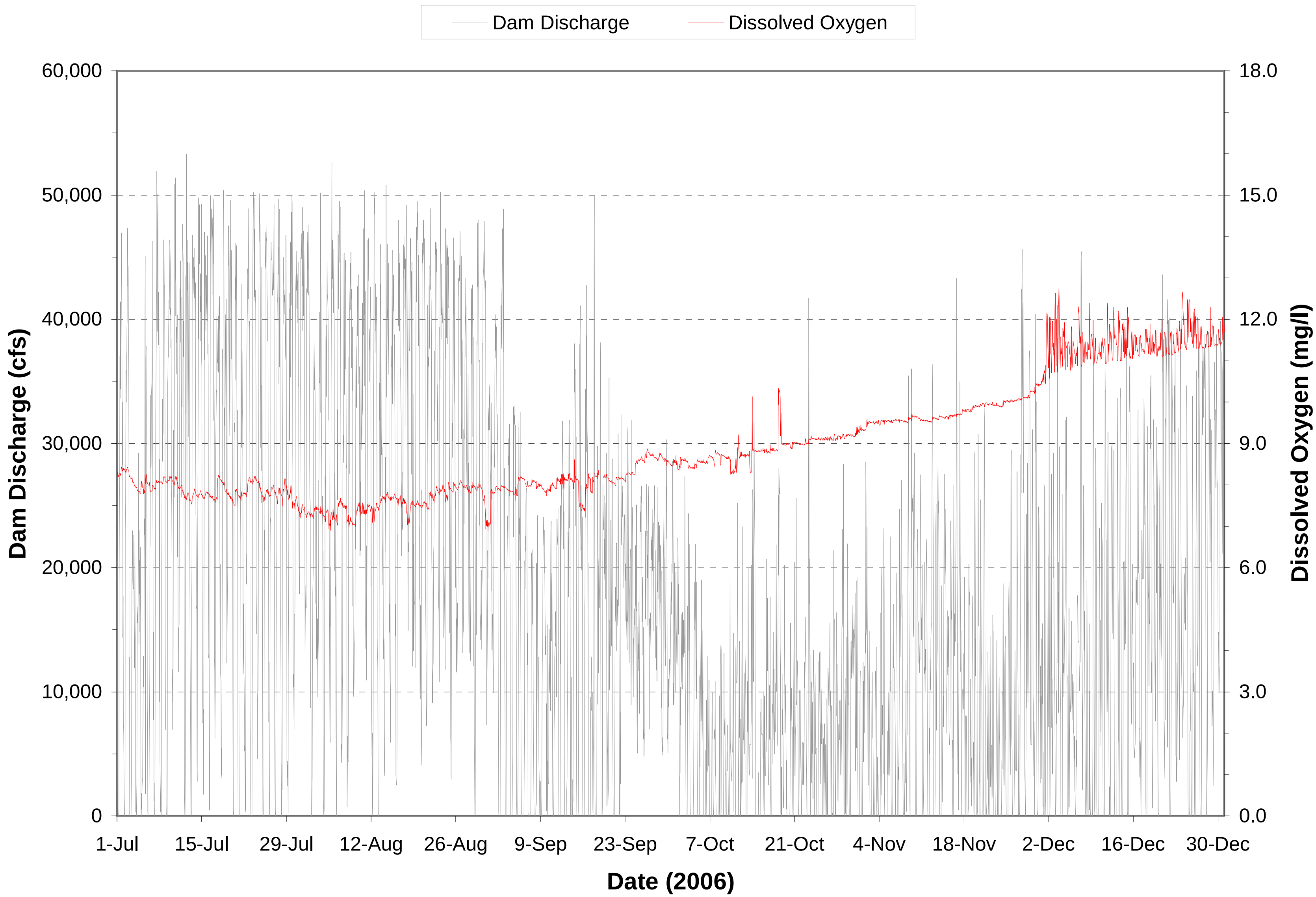


Plate 186. Hourly discharge and dissolved oxygen monitored at the Oahe Powerplant on water discharged through the dam during the period July through December 2006.

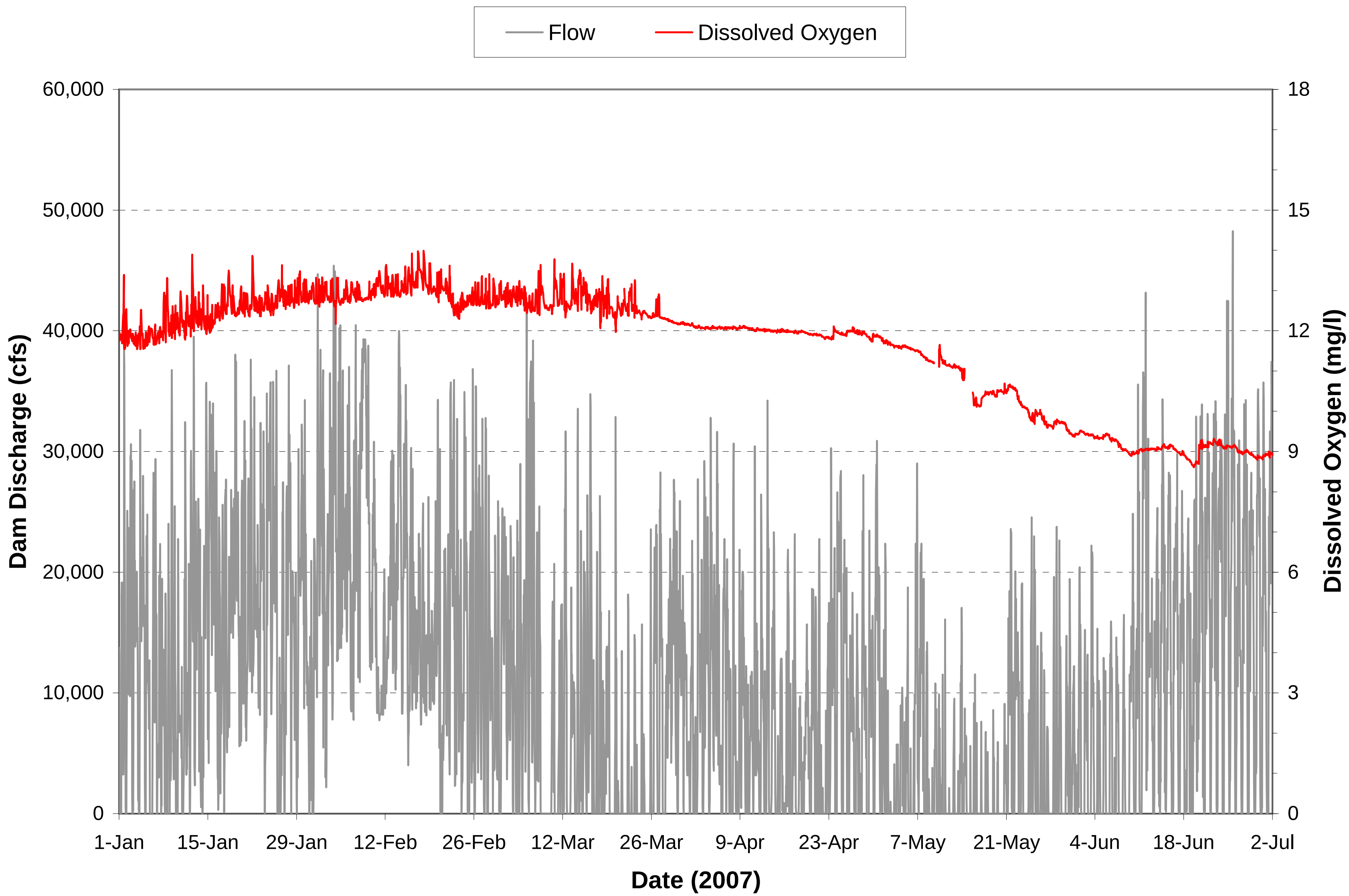


Plate 187. Hourly discharge and dissolved oxygen monitored at the Oahe powerplant on water discharged through the dam during the period January through June 2007.

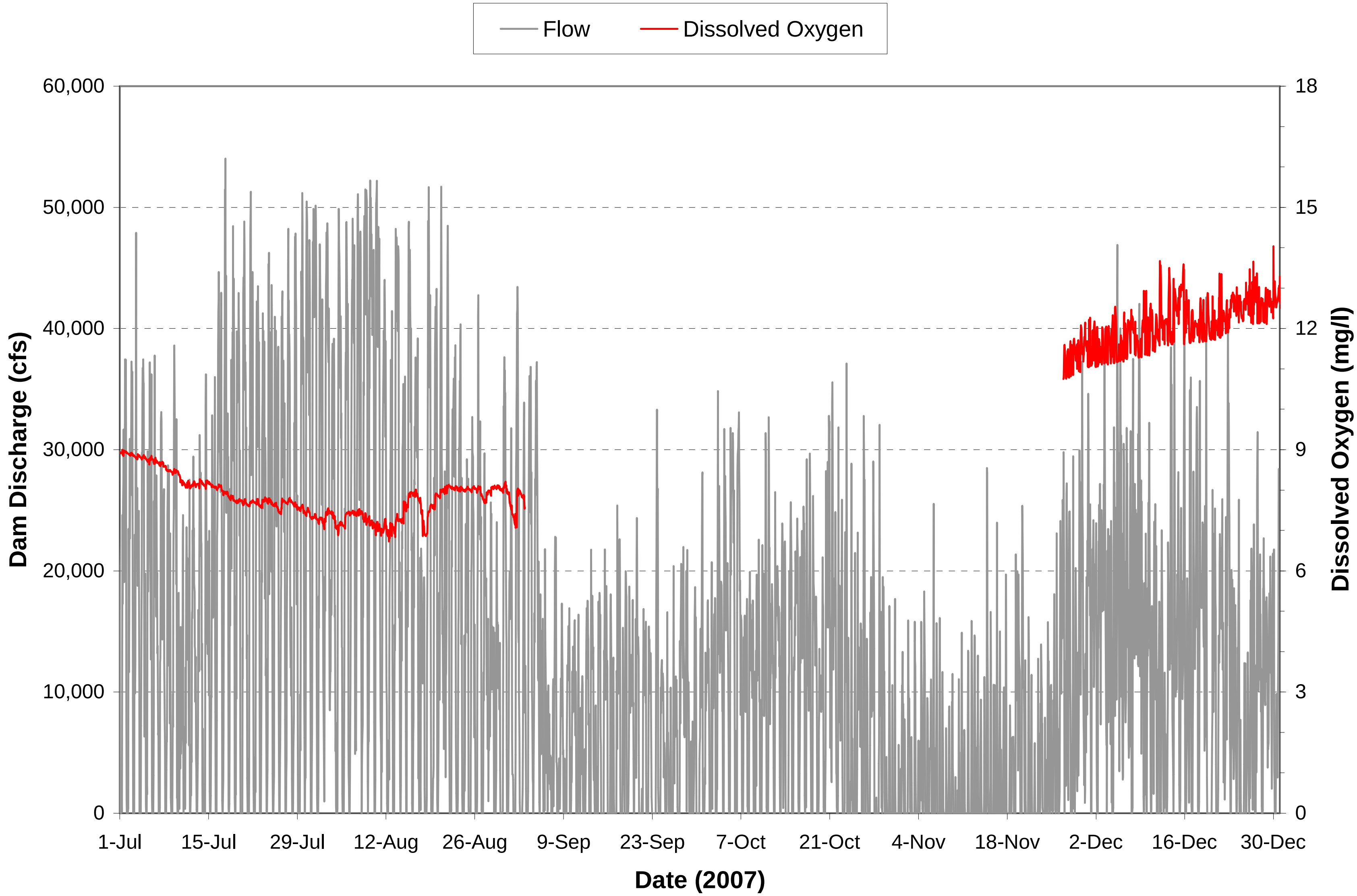


Plate 188. Hourly discharge and dissolved oxygen monitored at the Oahe Powerplant on water discharged through the dam during the period July through December 2007.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

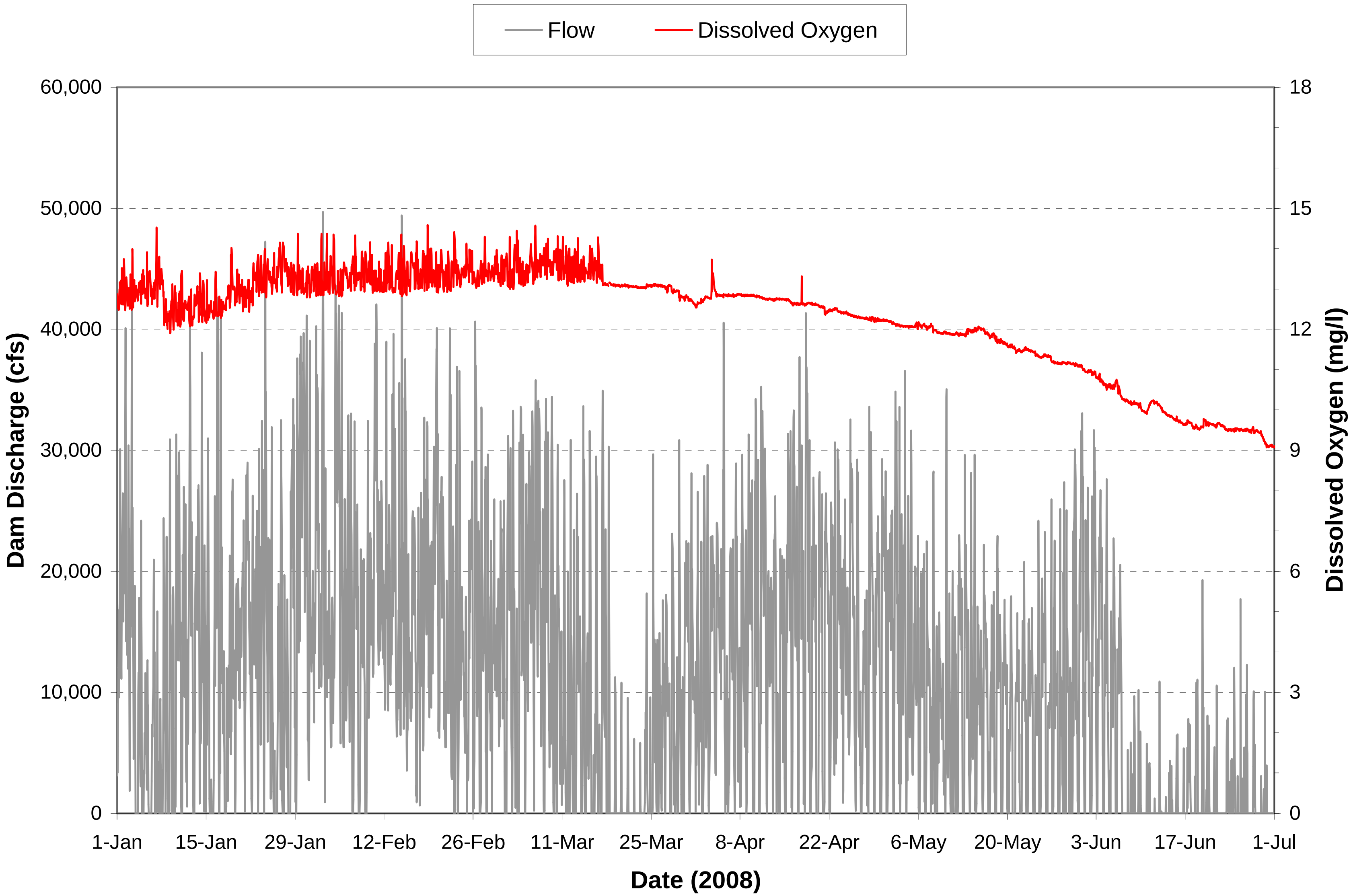


Plate 189. Hourly discharge and dissolved oxygen monitored at the Oahe powerplant on water discharged through the dam during the period January through June 2008.

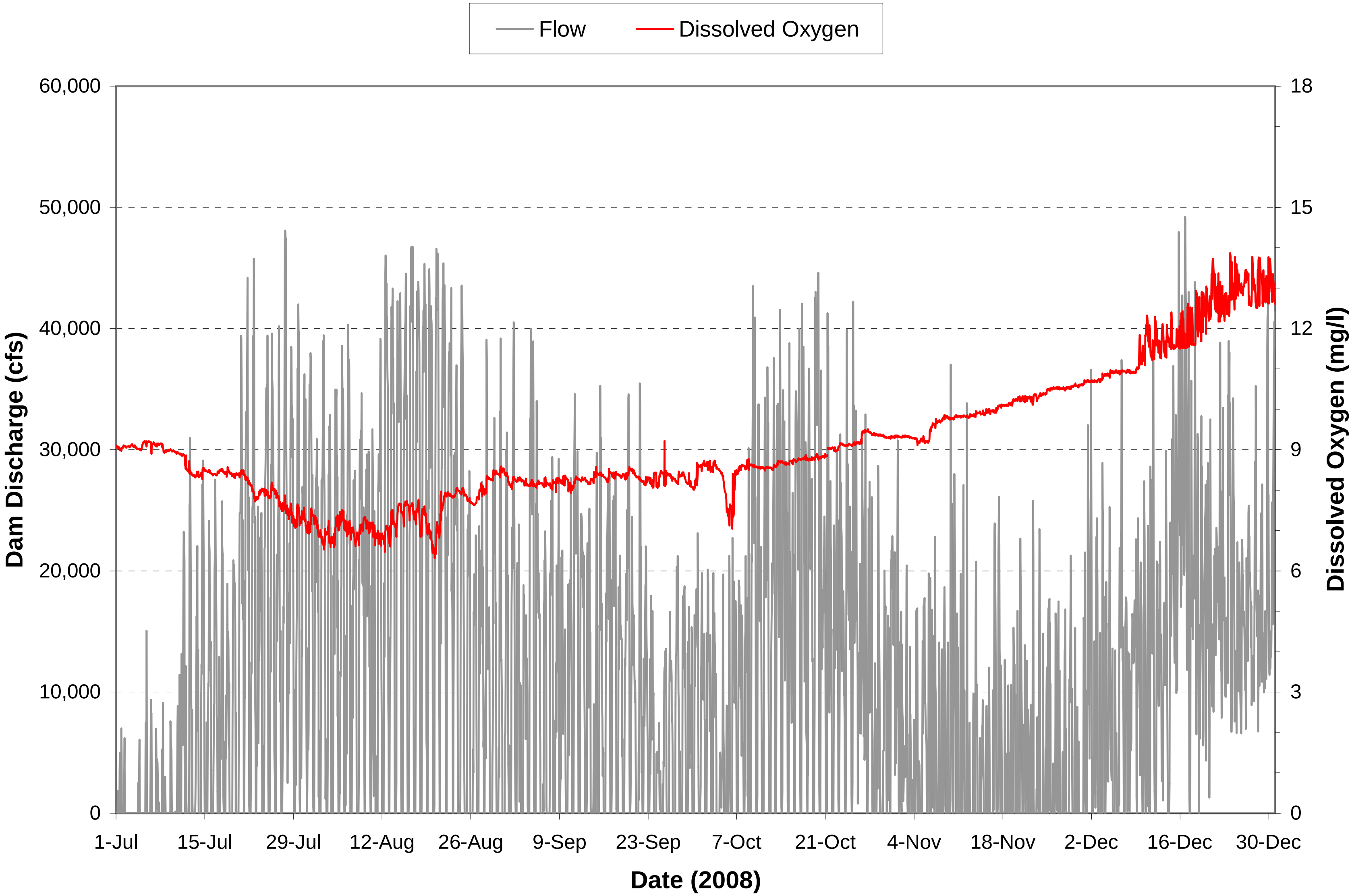


Plate 190. Hourly discharge and dissolved oxygen monitored at the Oahe Powerplant on water discharged through the dam during the period July through December 2008.

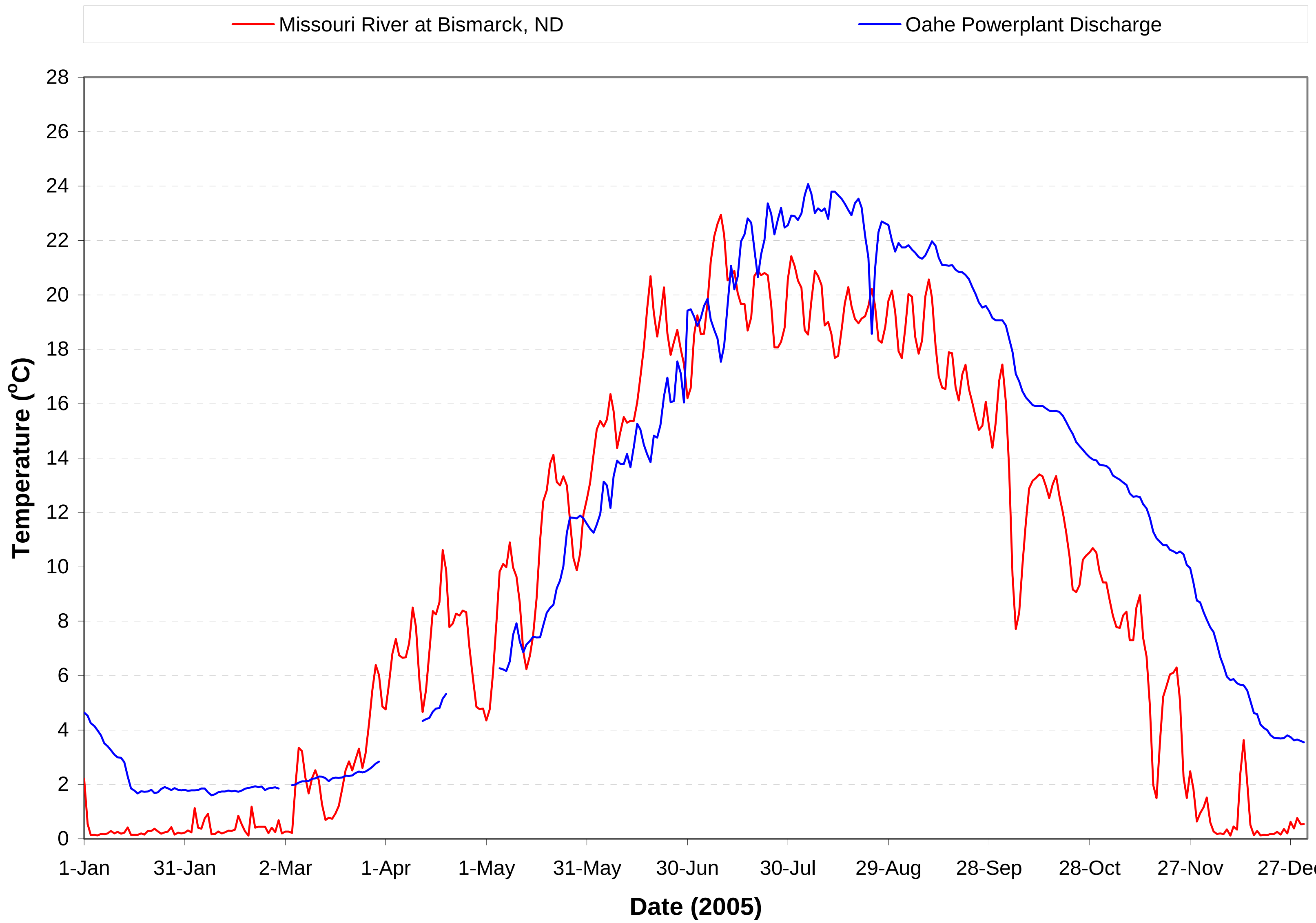


Plate 191. Mean daily water temperatures monitored at the Oahe Powerplant (i.e., site OAHPP1) and the Missouri River near Bismarck, North Dakota (i.e., site OAHNFMORR1) during 2005.
(Note: Gaps in temperature plots are periods when monitoring equipment was not operational.)

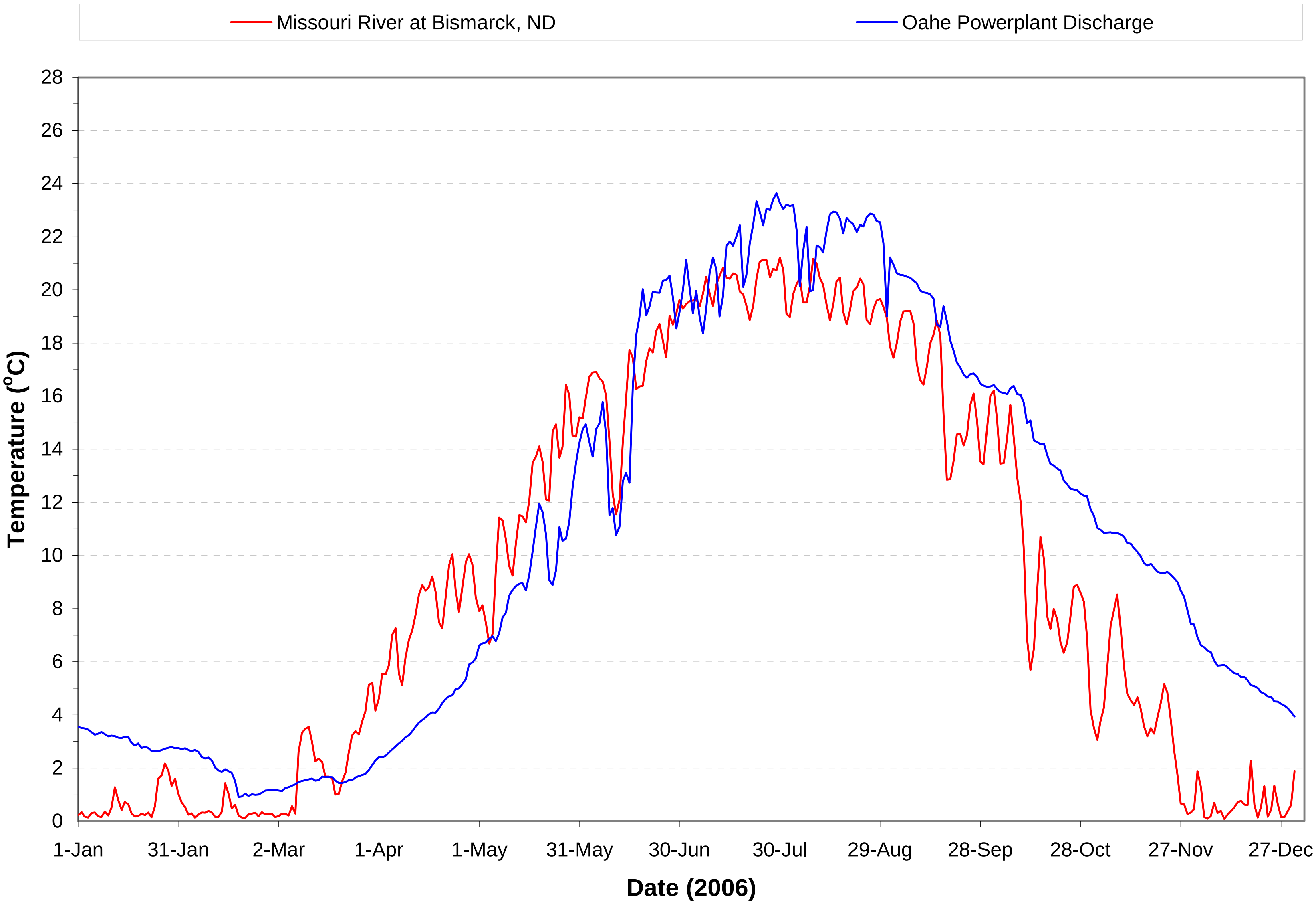


Plate 192. Mean daily water temperatures monitored at the Oahe Powerplant (i.e., site OAHPP1) and the Missouri River near Bismarck, North Dakota (i.e., site OAHNFMORR1) during 2006.

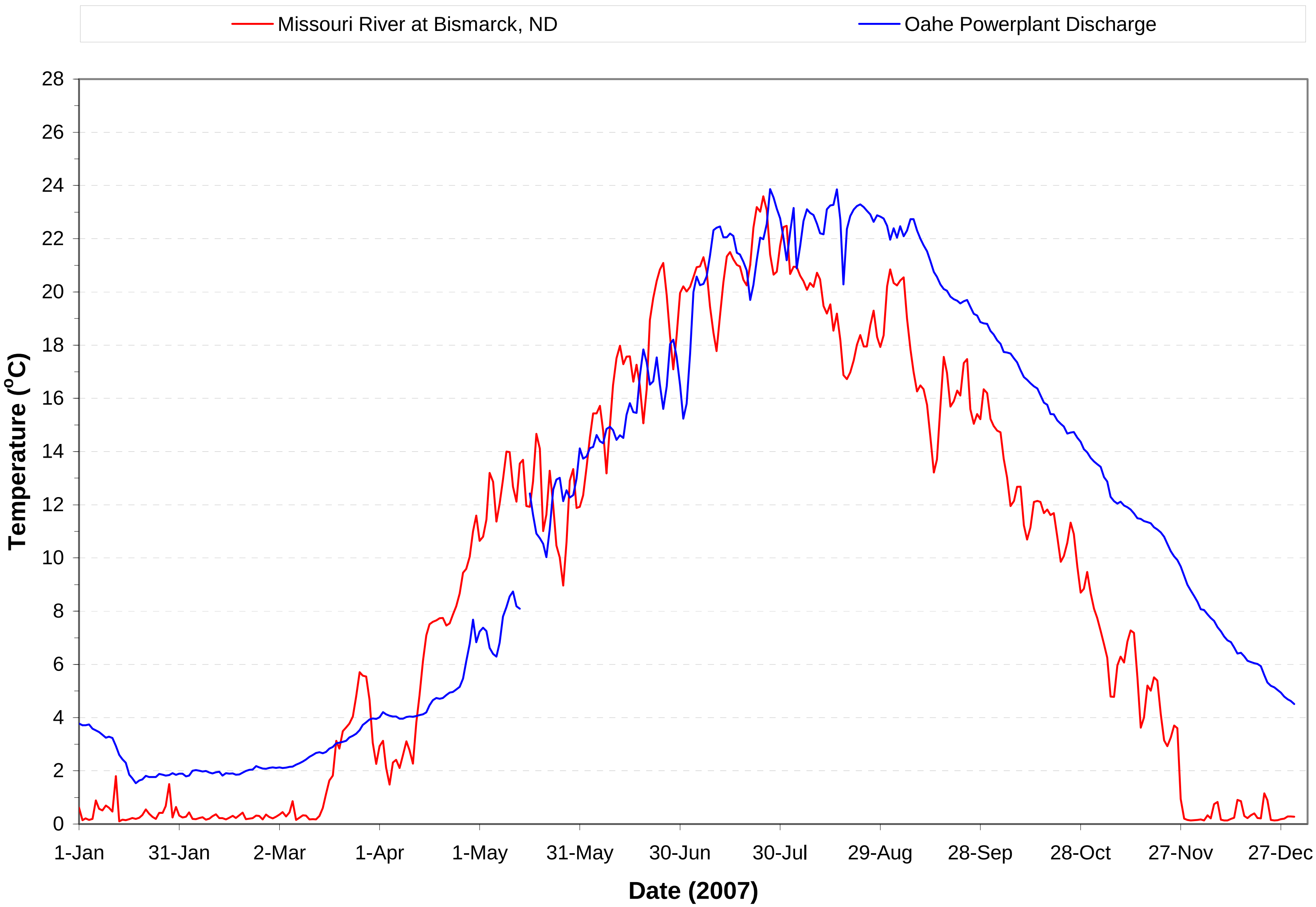


Plate 193. Mean daily water temperatures monitored at the Oahe Powerplant (i.e., site OAHPP1) and the Missouri River near Bismarck, North Dakota (i.e., site OAHNFMORR1) during 2007.

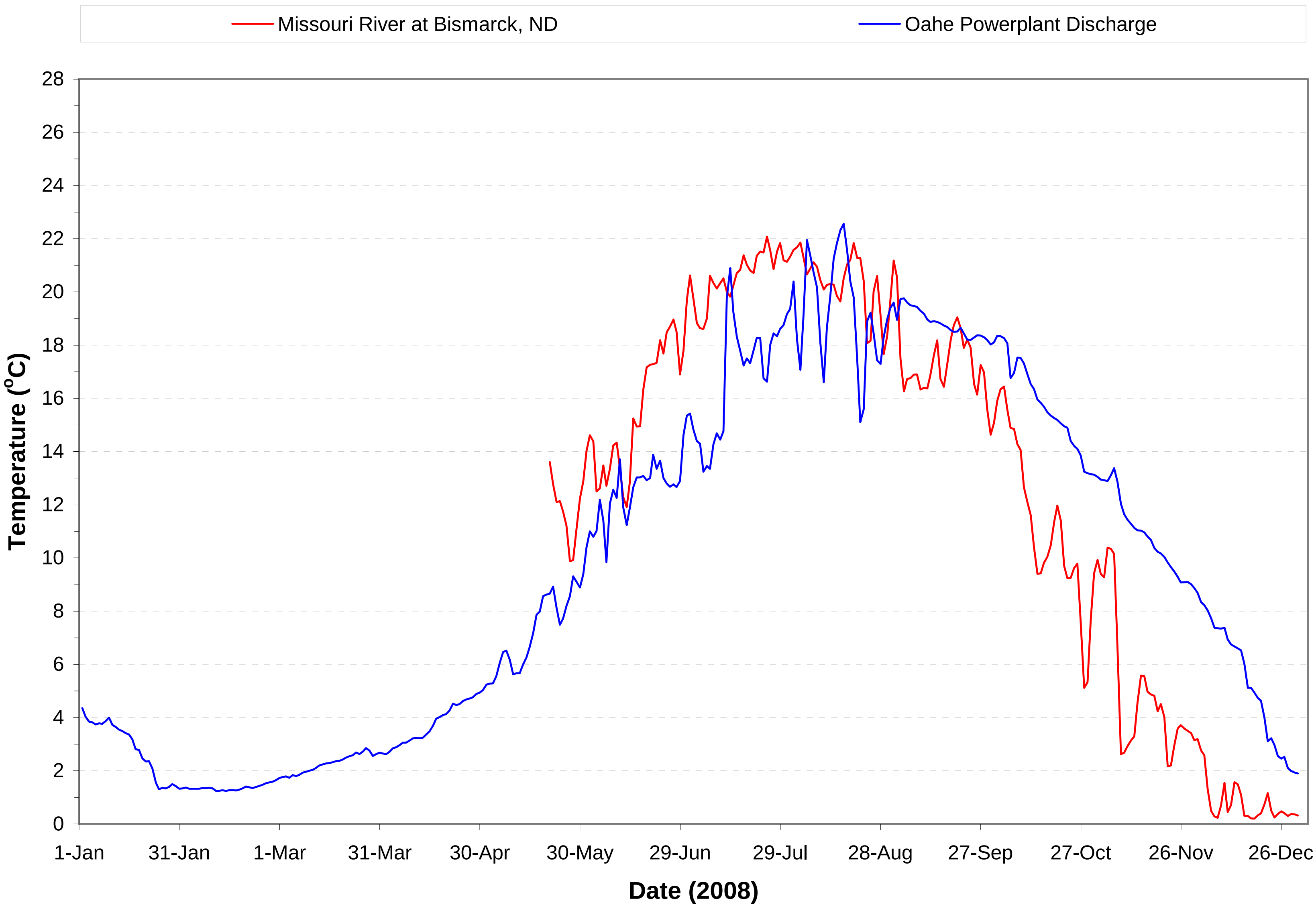


Plate 194. Mean daily water temperatures monitored at the Oahe Powerplant (i.e., site OAHPP1) and the Missouri River near Bismarck, North Dakota (i.e., site OAHNFMORR1) during 2008.

Plate 195. Summary of monthly (May through September) water quality conditions monitored in Big Bend Reservoir near Big Bend Dam (Site BBDLK0987A) during the 5-year period 2004 through 2008.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	25	1420.4	1420.4	1419.9	1420.9	-----	-----	-----
Water Temperature (C)	0.1	561	19.4	19.9	9.7	27.3	18.3[1,5]	349	62%
Hypolimnion Water Temperature (C)[E]	0.1	26	17.7	16.2	14.0	23.4	18.3[1,5]	12	46%
Dissolved Oxygen (mg/l)	0.1	561	8.1	8.0	3.1	10.8	6[1,6,8], 7[1,6,8]	24, 89	4%, 16%
Dissolved Oxygen (% Sat.)	0.1	561	91.1	92.9	37.2	108.7	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	535	8.2	8.0	5.4	10.8	5[3,6]	0	0%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	26	6.9	8.8	3.1	9.2	6[1,6,8]	12	46%
Specific Conductance (umho/cm)	1	560	684	698	546	796	-----	-----	-----
pH (S.U.)	0.1	515	8.4	8.4	7.8	9.0	6.5[1,2,6], 9.0[1,2,5], 9.5[4,5]	0	0%
Turbidity (NTUs)	1	559	5	4	n.d.	38	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	493	350	340	259	441	-----	-----	-----
Secchi Depth (in.)	1	25	86	74	40	228	-----	-----	-----
Alkalinity, Total (mg/l)	7	48	166	163	140	186	-----	-----	-----
Ammonia, Total (mg/l)	0.02	48	-----	0.04	n.d.	0 24	2.6 [1,5,9], 0.86 [1,7,9]	0	0%
Carbon, Total Organic (mg/l)	0.05	46	3.1	3.1	1.5	4.5	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	32	10	10	n.d.	20	-----	-----	-----
Chloride (mg/l)	1	32	11	11	9	12	175[1,5], 100[1,7], 438[2,5], 250[2,7]	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	532	-----	2	n.d.	14	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	24	-----	2	n.d.	7	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	48	480	472	440	560	1,750[2,5], 1,000[2,7], 3,500[4,5], 2,000[4,7]	0	0%
Iron, Total (ug/l)	40	20	118	100	n.d.	240	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	48	-----	0.3	n.d.	0.8	-----	-----	-----
Manganese, Total (ug/l)	2	20	28	30	4	61	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	48	-----	n.d.	n.d.	0 11	10[2,5]	0	0%
Phosphorus, Dissolved (mg/l)	0.02	28	-----	n.d.	n.d.	0.18	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	48	0.04	0.03	n.d.	0 24	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	48	-----	n.d.	n.d.	0 16	-----	-----	-----
Sulfate (mg/l)	1	34	202	201	165	230	875[2,5], 500[2,7]	0	0%
Suspended Solids, Total (mg/l)	4	48	-----	n.d.	n.d.	7	53[1,5], 30[1,7]	0	0%
Microcystin, Total (ug/l)	0.2	18	-----	n.d.	n.d.	0.3	-----	-----	-----
Coldwater Permanent Fish Life Propagation Habitat[F]	-----	25	-----	-----	-----	-----	D.O ≥ 6 mg/l W.Temp. ≤ 18 3 C	15	60%

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for the protection of coldwater permanent fish life propagation waters.
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of immersion and limited contact recreation waters (applies only to epilimnion and metalimnion if water body stratified).
- (4) Criteria for the protection of commerce and industry waters.
- (5) Daily maximum criterion (monitoring results directly comparable to criterion).
- (6) Daily minimum criterion (monitoring results directly comparable to criterion).
- (7) 30-day average criterion (monitoring results not directly comparable to criterion).
- (8) The 7.0 mg/l criterion applies to spawning areas during spawning season, and the 6.0 mg/l criterion applies otherwise.
- (9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5 C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1 C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5 C occurs over a 1-meter depth increment. A defined hypolimnion was monitored on 5 of the 25 occasions (i.e., 20%) that monthly depth profiles were measured from May through September.

(F) Evaluates the occurrence of Coldwater Permanent Fish Life Propagation habitat (i e., at least a 1-meter layer of water with a temperature ≤ 18.3 C and dissolved oxygen ≥ 6 mg/l). The "No. of Obs." is the number of monthly water column depth-profiles measured. The "No. of WQS Exceedences" is the number of occurrences where no Coldwater Permanent Fish Life Propagation habitat was present anywhere within the measured water column depth-profile.

Plate 196. Summary of monthly (June through September) water quality conditions monitored at Big Bend Reservoir in the North Bend area (site BBDLK1004DW) during 2008.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	4	1420.3	1420.3	1419.7	1420.8	-----	-----	-----
Water Temperature (C)	0.1	71	20.6	19.8	14.5	26.8	18.3[1,5]	53	75%
Hypolimnion Water Temperature (C)[E]	0.1	4	14.6	14.6	14.5	14.7	18.3[1,5]	0	0%
Dissolved Oxygen (mg/l)	0.1	71	8.3	8.5	5.2	9.7	6[1,6,8], 7[1,6,8]	2, 12	3%, 17%
Dissolved Oxygen (% Sat.)	0.1	71	95.3	96.7	65.3	113.5	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	67	8.2	8.5	5.2	9.7	5[3,6]	0	0%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	4	8.9	8.9	8.8	9.0	6[1,6,8]	0	0%
Specific Conductance (umho/cm)	1	71	720	723	704	731	-----	-----	-----
pH (S.U.)	0.1	71	8.3	8.3	7.9	8.6	6.5[1,2,6], 9.0[1,2,5], 9.5[4,5]	0	0%
Turbidity (NTUs)	1	71	4	4	n.d.	16	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	53	295	304	254	326	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	68	3	3	1	5	-----	-----	-----
Secchi Depth (in)	1	4	80	63	48	146	-----	-----	-----
Coldwater Permanent Fish Life Propagation Habitat[f]	-----	4	-----	-----	-----	-----	D.O ≥ 6 mg/l W.Temp. ≤ 18 3 C	3	75%

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.
- (1) Criteria for the protection of coldwater permanent fish life propagation waters.
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of immersion and limited contact recreation waters (applies only to epilimnion and metalimnion if water body stratified).
- (4) Criteria for the protection of commerce and industry waters.
- (5) Daily maximum criterion (monitoring results directly comparable to criterion).
- (6) Daily minimum criterion (monitoring results directly comparable to criterion).
- (7) 30-day average criterion (monitoring results not directly comparable to criterion).
- (8) The 7.0 mg/l criterion applies to spawning areas during spawning season, and the 6.0 mg/l criterion applies otherwise.
- (9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5 C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1 C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5 C occurs over a 1-meter depth increment. A defined hypolimnion was monitored on 1 of the 4 occasions (i.e., 25%) that monthly depth profiles were measured from June through September.

(F) Evaluates the occurrence of Coldwater Permanent Fish Life Propagation habitat (i e., at least a 1-meter layer of water with a temperature ≤ 18.3 C and dissolved oxygen ≥ 6 mg/l). The "No. of Obs." is the number of monthly water column depth-profiles measured. The "No. of WQS Exceedences" is the number of occurrences where no Coldwater Permanent Fish Life Propagation habitat was present anywhere within the measured water column depth-profile.

Plate 197. Summary of monthly (May through September) water quality conditions monitored at Big Bend Reservoir in the Iron Nation area (Site BBDLK1020DW) during 2008.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	**No. of Obs.**	**Mean[C]**	**Median**	**Min.**	**Max.**	**State WQS Criteria[D]**	**No. of WQS Exceedences**	**Percent WQS Exceedence**
Pool Elevation (ft-msl)	0.1	4	1420.3	1420.3	1419.8	1420.9	-----	-----	-----
Water Temperature (C)	0.1	48	20.6	20.9	16.9	27.3	18.3[1,5]	26	54%
Hypolimnion Water Temperature (C)[E]	0.1	0[G]	-----	-----	-----	-----	18.3[1,5]	-----	-----
Dissolved Oxygen (mg/l)	0.1	48	8.3	8.7	6.4	10.3	6[1,6,8], 7[1,6,8]	0, 6	0%, 13%
Dissolved Oxygen (% Sat.)	0.1	48	95.7	96.4	75.9	133.9	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	48	8.3	8.7	6.4	10.3	5[3,6]	0	0%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	0[G]	-----	-----	-----	-----	6[1,6,8]	-----	-----
Specific Conductance (umho/cm)	1	48	725	722	700	770	-----	-----	-----
pH (S.U.)	0.1	48	8.3	8.4	8.0	8.6	6.5[1,2,6], 9.0[1,2,5], 9.5[4,5]	0	0%
Turbidity (NTUs)	1	48	8	8	4	18	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	36	294	307	256	322	-----	-----	-----
Secchi Depth (in.)	1	4	39	39	29	48	-----	-----	-----
Alkalinity, Total (mg/l)	7	8	159	158	154	165	-----	-----	-----
Ammonia, Total (mg/l)	0.02	8	-----	n.d.	n.d.	0 20	3.1[1,5,9], 0 97 [1,7,9]	0	0%
Carbon, Total Organic (mg/l)	0.05	8	3.2	3.3	2.6	4.0	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	8	13	13	9	18	-----	-----	-----
Chloride (mg/l)	1	8	12	12	11	13	175[1,5], 100[1,7], 438[2,5], 250[2,7]	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	47	3	3	2	7	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	4	7	7	6	9	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	8	495	485	464	546	1,750[2,5], 1,000[2,7], 3,500[4,5], 2,000[4,7]	0	0%
Iron, Total (ug/l)	40	4	368	365	220	520	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	8	0.6	0.5	0.2	1.4	-----	-----	-----
Manganese, Total (ug/l)	2	4	53	50	30	80	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	8	-----	n.d.	n.d.	0.05	10[2,5]	0	0%
Phosphorus, Dissolved (mg/l)	0.02	8	-----	0.02	n.d.	0.04	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	8	0.06	0.04	0.03	0 21	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	8	-----	n.d.	n.d.	0.03	-----	-----	-----
Sulfate (mg/l)	1	8	198	199	182	217	875[2,5], 500[2,7]	0	0%
Suspended Solids, Total (mg/l)	4	8	-----	n.d.	n.d.	8	53[1,5], 30[1,7]	0	0%
Microcystin, Total (ug/l)	0.2	4	-----	n.d.	n.d.	0.2	-----	-----	-----
Coldwater Permanent Fish Life Propagation Habitat[F]	-----	4	-----	-----	-----	-----	D.O ≥ 6 mg/l W.Temp. ≤ 18 3 C	2	50%

n.d. = Not detected.

[A] Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

[B] Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

[C] Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

[D] Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- [1] Criteria for the protection of coldwater permanent fish life propagation waters.
- [2] Criteria for the protection of domestic water supply waters.
- [3] Criteria for the protection of immersion and limited contact recreation waters (applies only to epilimnion and metalimnion if water body stratified).
- [4] Criteria for the protection of commerce and industry waters.
- [5] Daily maximum criterion (monitoring results directly comparable to criterion).
- [6] Daily minimum criterion (monitoring results directly comparable to criterion).
- [7] 30-day average criterion (monitoring results not directly comparable to criterion).
- [8] The 7.0 mg/l criterion applies to spawning areas during spawning season, and the 6.0 mg/l criterion applies otherwise.
- [9] Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

[E] A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5 C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1 C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5 C occurs over a 1-meter depth increment.

[F] Evaluates the occurrence of Coldwater Permanent Fish Life Propagation habitat (i.e., at least a 1-meter layer of water with a temperature ≤ 18.3 C and dissolved oxygen ≥ 6 mg/l). The "No. of Obs." is the number of monthly water column depth-profiles measured. The "No. of WQS Exceedences" is the number of occurrences where no Coldwater Permanent Fish Life Propagation habitat was present anywhere within the measured water column depth-profile.

[G] Depth-profiles did not indicate the presence of a hypolimnion during monitored period. It is assumed that the water column experienced complete mixing due to shallower water depths during the monitored period.

Plate 198. Summary of monthly (June through September) water quality conditions monitored at Big Bend Reservoir in the Cedar Creek area (site BBDLK1036DW) during 2008.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	4	1420.3	1420.3	1420.0	1420.6	-----	-----	-----
Water Temperature (C)	0.1	24	20.4	20.4	16.9	24 3	18.3[1,5]	12	50%
Hypolimnion Water Temperature (C)[E]	0.1	0[G]	-----	-----	-----	-----	18.3[1,5]	-----	-----
Dissolved Oxygen (mg/l)	0.1	24	8.5	8.6	7.6	9 2	6[1,6,8], 7[1,6,8]	0	0%
Dissolved Oxygen (% Sat.)	0.1	24	98.1	98.3	92.8	104.9	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	24	8.5	8.6	7.6	9 2	5[3,6]	0	0%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	0[G]	-----	-----	-----	-----	6[1,6,8]	-----	-----
Specific Conductance (umho/cm)	1	24	783	745	719	908	-----	-----	-----
pH (S.U.)	0.1	24	8.4	8.5	8.2	8.6	6.5[1,2,6], 9.0[1,2,5], 9.5[4,5]	0	0%
Turbidity (NTUs)	1	24	33	33	12	65	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	24	336	319	268	444	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	24	6	6	3	10	-----	-----	-----
Secchi Depth (in)	1	4	14	14	9	20	-----	-----	-----
Coldwater Permanent Fish Life Propagation Habitat[F]	-----	4	-----	-----	-----	-----	D.O ≥ 6 mg/l W.Temp. ≤ 18 3 C	2	50%

n.d. = Not detected.

[A] Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

[B] Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

[C] Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

[D] Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.
- (1) Criteria for the protection of coldwater permanent fish life propagation waters.
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of immersion and limited contact recreation waters (applies only to epilimnion and metalimnion if water body stratified).
- (4) Criteria for the protection of commerce and industry waters.
- (5) Daily maximum criterion (monitoring results directly comparable to criterion).
- (6) Daily minimum criterion (monitoring results directly comparable to criterion).
- (7) 30-day average criterion (monitoring results not directly comparable to criterion).
- (8) The 7.0 mg/l criterion applies to spawning areas during spawning season, and the 6.0 mg/l criterion applies otherwise.
- (9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

[E] A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5 C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1 C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5 C occurs over a 1-meter depth increment.

[F] Evaluates the occurrence of Coldwater Permanent Fish Life Propagation habitat (i e., at least a 1-meter layer of water with a temperature ≤ 18.3 C and dissolved oxygen ≥ 6 mg/l). The "No. of Obs." is the number of monthly water column depth-profiles measured. The "No. of WQS Exceedences" is the number of occurrences where no Coldwater Permanent Fish Life Propagation habitat was present anywhere within the measured water column depth-profile.

[G] Depth-profiles did not indicate the presence of a hypolimnion during monitored period. It is assumed that the water column experienced complete mixing due to shallower water depths during the monitored period.

Plate 199. Summary of monthly (May through September) water quality conditions monitored at Big Bend Reservoir in the Antelope Creek area (Site BBDLK1055DW) during 2008.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	4	1420.3	1420.2	1420.0	1420.7	-----	-----	-----
Water Temperature (C)	0.1	20	19.9	20.0	17.3	22.2	18.3[1,5]	15	75%
Hypolimnion Water Temperature (C)[E]	0.1	0[G]	-----	-----	-----	-----	18.3[1,5]	-----	-----
Dissolved Oxygen (mg/l)	0.1	20	8.5	8.5	7.7	9.4	6[1,6,8], 7[1,6,8]	0	0%
Dissolved Oxygen (% Sat.)	0.1	20	97.4	97.4	90.2	104.9	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	20	8.5	8.5	7.7	9.4	5[3,6]	0	0%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	0[G]	-----	-----	-----	-----	6[1,6,8]	-----	-----
Specific Conductance (umho/cm)	1	20	747	718	712	843	-----	-----	-----
pH (S.U.)	0.1	20	8.4	8.5	8.1	8.6	6.5[1,2,6], 9.0[1,2,5], 9.5[4,5]	0	0%
Turbidity (NTUs)	1	20	64	42	10	188	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	20	333	316	267	433	-----	-----	-----
Secchi Depth (in.)	1	4	13	10	6	26	-----	-----	-----
Alkalinity, Total (mg/l)	7	4	149	157	122	158	-----	-----	-----
Ammonia, Total (mg/l)	0.02	4	-----	0.03	n.d.	0 27	2.6 [1,5,9], 0.86 [1,7,9]	0	0%
Carbon, Total Organic (mg/l)	0.05	4	4.4	3.0	2.6	9.1	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	4	13	13	5	20	-----	-----	-----
Chloride (mg/l)	1	4	12	12	10	16	175[1,5], 100[1,7], 438[2,5], 250[2,7]	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	19	4	5	2	7	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	4	6	5	3	11	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	4	526	526	464	586	1,750[2,5], 1,000[2,7], 3,500[4,5], 2,000[4,7]	0	0%
Kjeldahl N, Total (mg/l)	0.1	4	2.6	0.5	0.4	9.1	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	4	-----	n.d.	n.d.	1 20	10[2,5]	0	0%
Phosphorus, Dissolved (mg/l)	0.02	4	-----	0.02	n.d.	0.04	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	4	0.11	0.07	0.04	0 26	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	4	-----	n.d.	n.d.	0.04	-----	-----	-----
Sulfate (mg/l)	1	4	217	202	190	274	875[2,5], 500[2,7]	0	0%
Suspended Solids, Total (mg/l)	4	4	89	30	12	285	53[1,5], 30[1,7]	1, 2	25%, 50%
Microcystin, Total (ug/l)	0.2	4	-----	n.d.	n.d.	0.2	-----	-----	-----
Coldwater Permanent Fish Life Propagation Habitat[F]	-----	4	-----	-----	-----	-----	D.O ≥ 6 mg/l W.Temp. ≤ 18 3 C	3	75%

n.d. = Not detected.

[A] Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

[B] Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

[C] Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

[D] Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.
- (1) Criteria for the protection of coldwater permanent fish life propagation waters.
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of immersion and limited contact recreation waters (applies only to epilimnion and metalimnion if water body stratified).
- (4) Criteria for the protection of commerce and industry waters.
- (5) Daily maximum criterion (monitoring results directly comparable to criterion).
- (6) Daily minimum criterion (monitoring results directly comparable to criterion).
- (7) 30-day average criterion (monitoring results not directly comparable to criterion).
- (8) The 7.0 mg/l criterion applies to spawning areas during spawning season, and the 6.0 mg/l criterion applies otherwise.
- (9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

[E] A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5 C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1 C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5 C occurs over a 1-meter depth increment.

[F] Evaluates the occurrence of Coldwater Permanent Fish Life Propagation habitat (i e., at least a 1-meter layer of water with a temperature ≤ 18.3 C and dissolved oxygen ≥ 6 mg/l). The "No. of Obs." is the number of monthly water column depth-profiles measured. The "No. of WQS Exceedences" is the number of occurrences where no Coldwater Permanent Fish Life Propagation habitat was present anywhere within the measured water column depth-profile.

[G] Depth-profiles did not indicate the presence of a hypolimnion during monitored period. It is assumed that the water column experienced complete mixing due to shallower water depths during the monitored period.

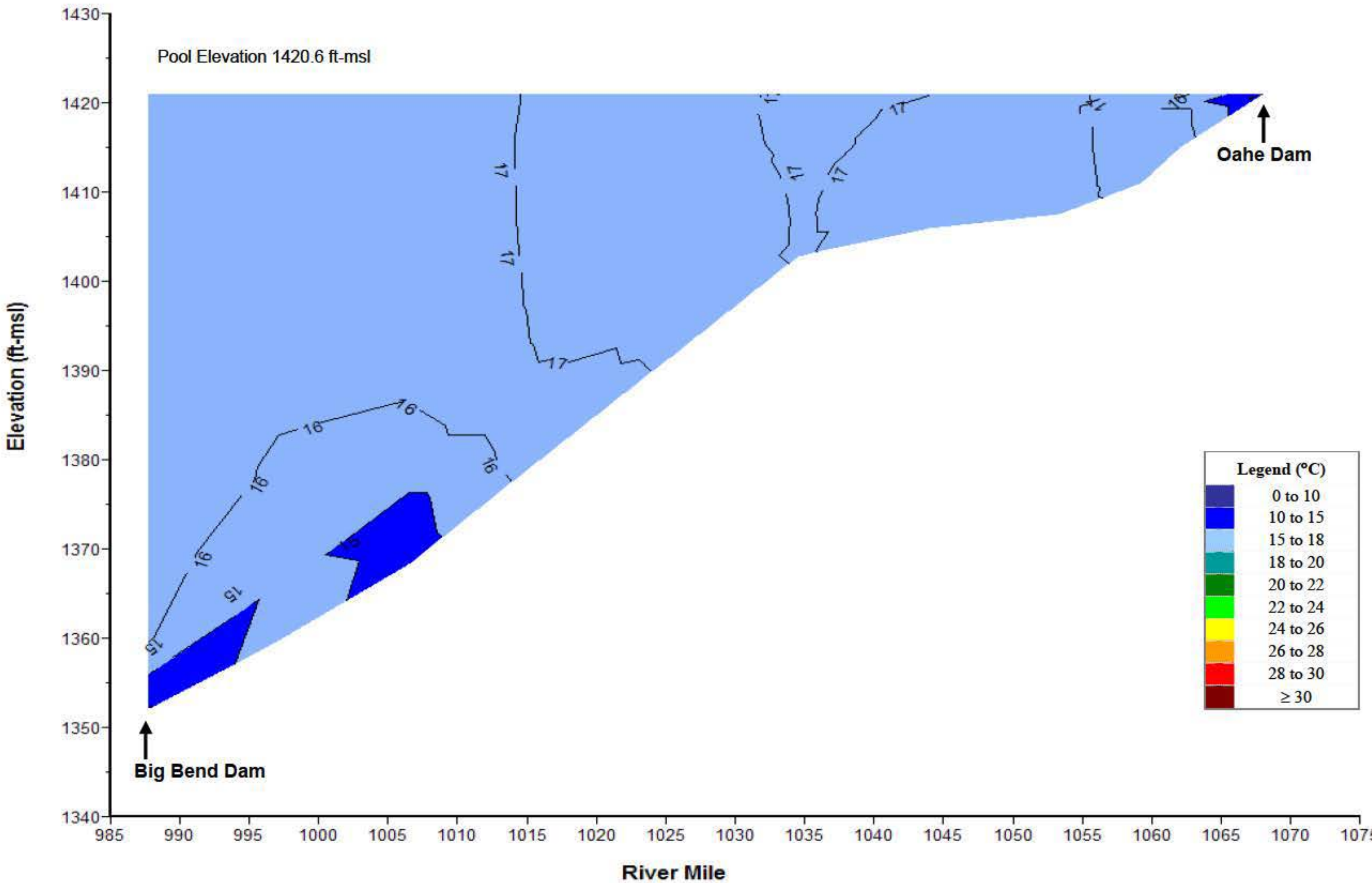


Plate 200. Longitudinal water temperature (°C) contour plot of Big Bend Reservoir based on depth-profile water temperatures measured at sites BBDLK0987A, BBDLK1004DW, BBDLK1020DW, BBDLK1036DW, BBDLK1055DW and OAHPP1 on June 10, 2008.

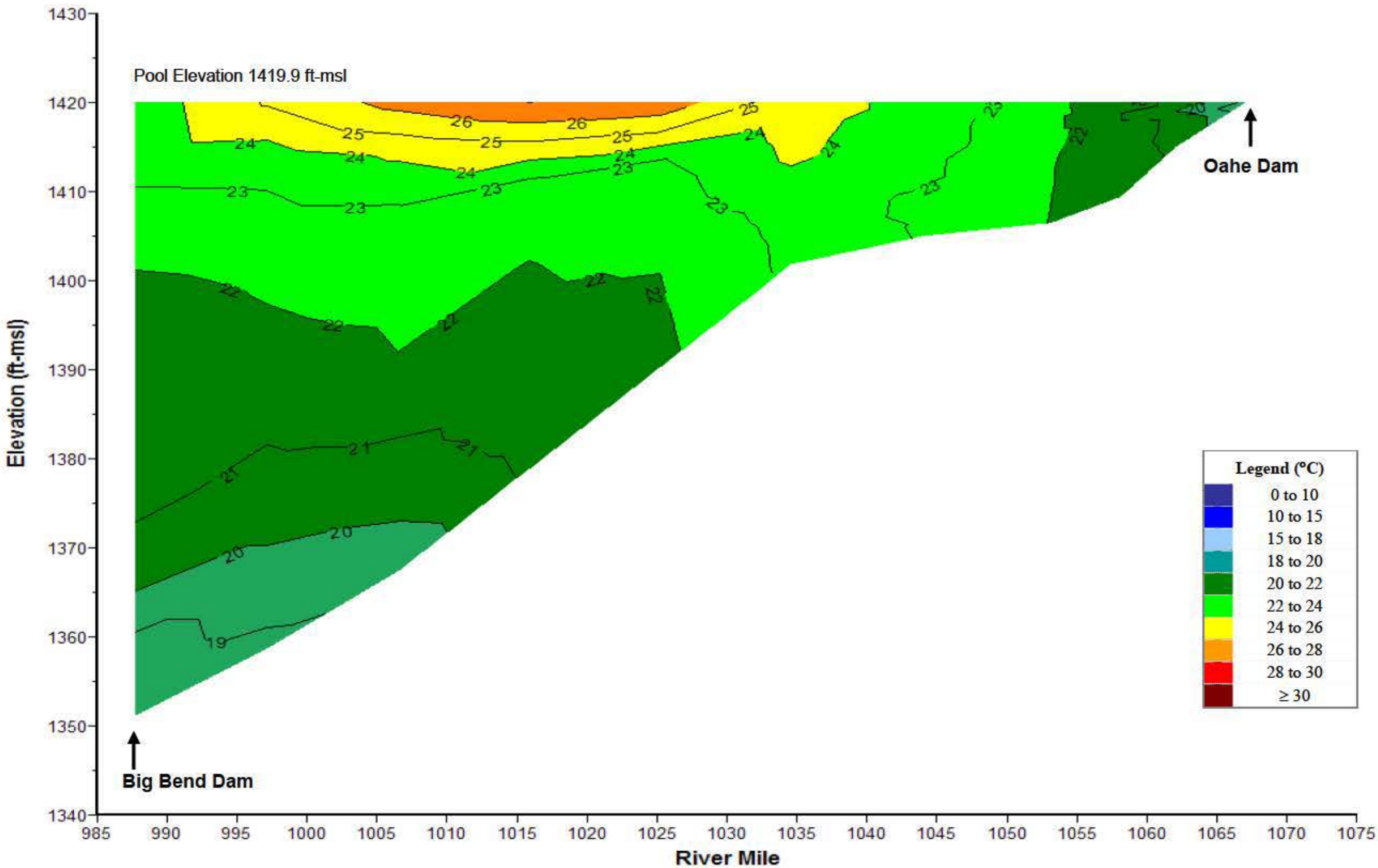


Plate 201. Longitudinal water temperature (°C) contour plot of Big Bend Reservoir based on depth-profile water temperatures measured at sites BBDLK0987A, BBDLK1004DW, BBDLK1020DW, BBDLK1036DW, BBDLK1055DW and OAHPP1 on July 16, 2008.

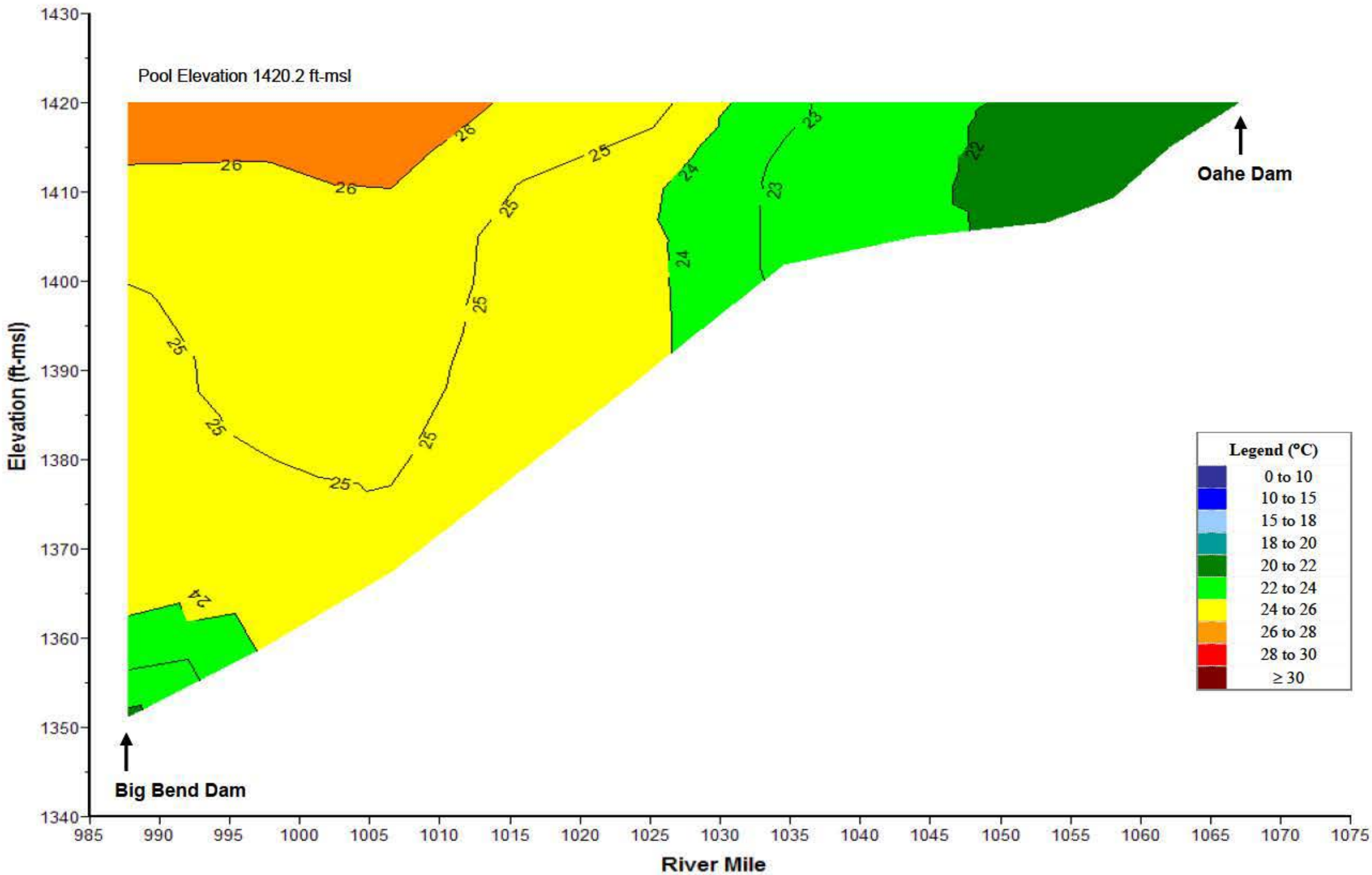


Plate 202. Longitudinal water temperature (°C) contour plot of Big Bend Reservoir based on depth-profile water temperatures measured at sites BBDLK0987A, BBDLK1004DW, BBDLK1020DW, BBDLK1036DW, BBDLK1055DW and OAHPP1 on August 12, 2008.

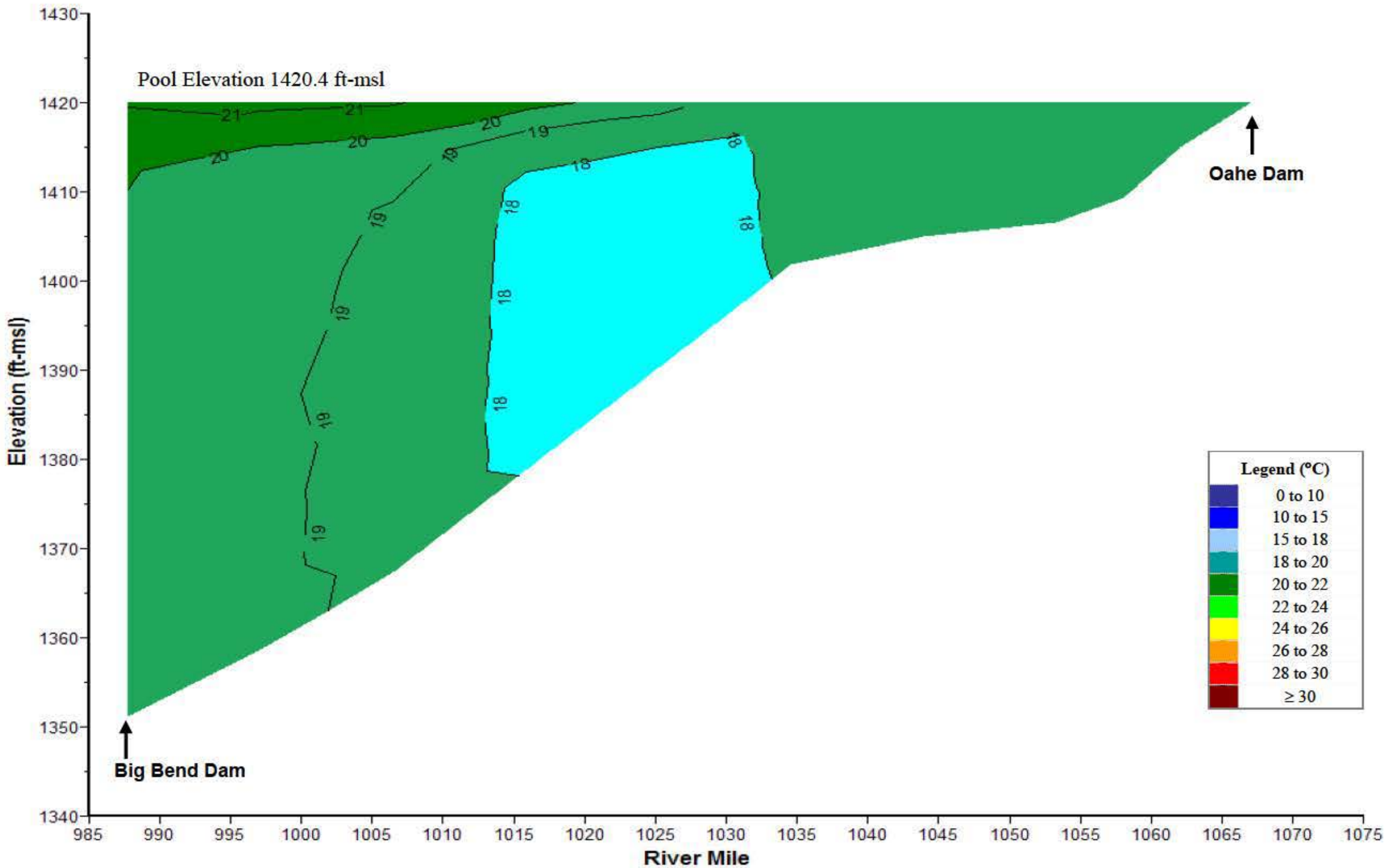


Plate 203. Longitudinal water temperature (°C) contour plot of Big Bend Reservoir based on depth-profile water temperatures measured at sites BBDLK0987A, BBDLK1004DW, BBDLK1020DW, BBDLK1036DW, BBDLK1055DW and OAHPP1 on September 16, 2008.

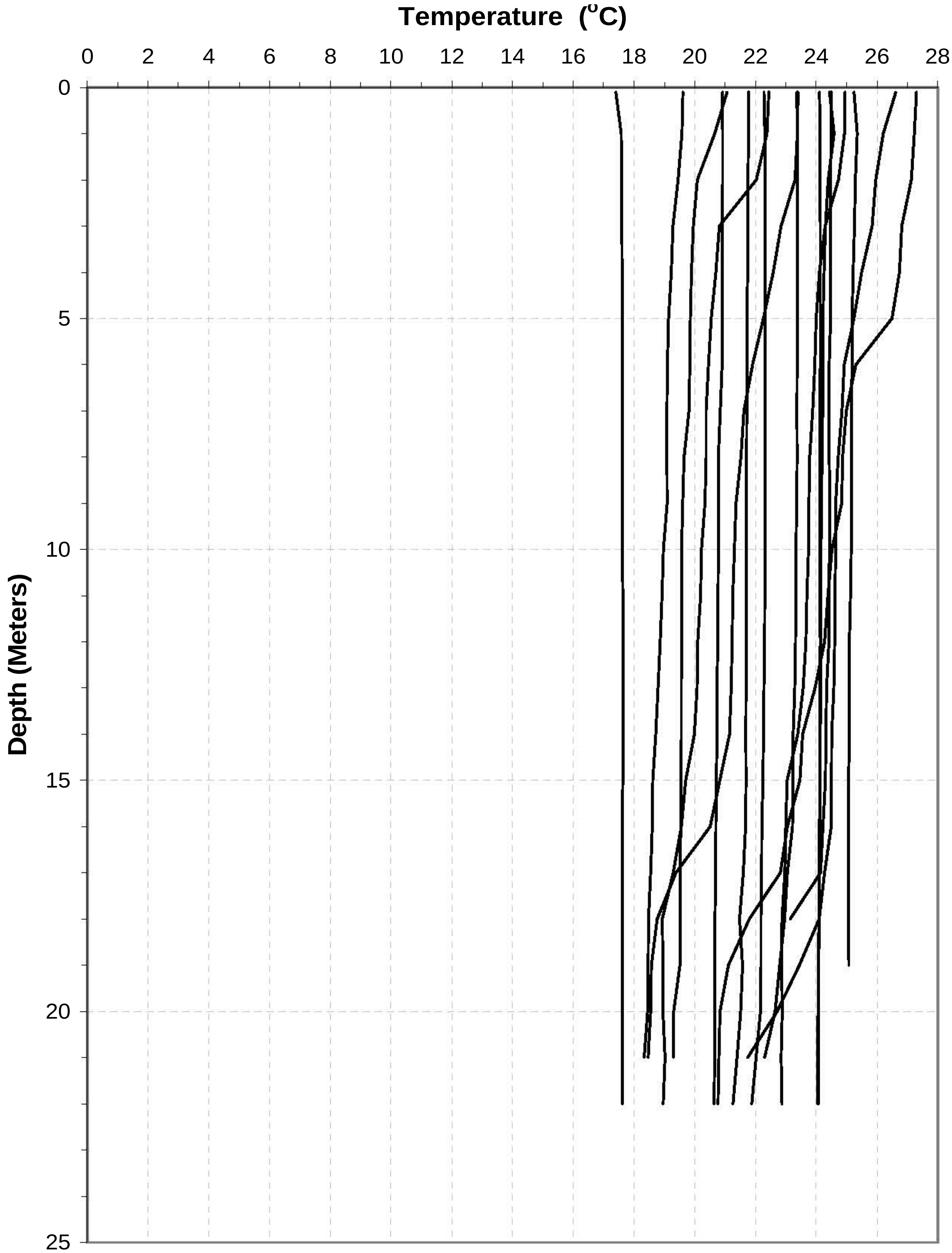


Plate 204. Temperature depth profiles for Big Bend Reservoir generated from data collected at the near-dam, deepwater ambient monitoring site (i.e., BBDLK0987A) during the summer months of the 5-year period 2004 to 2008.

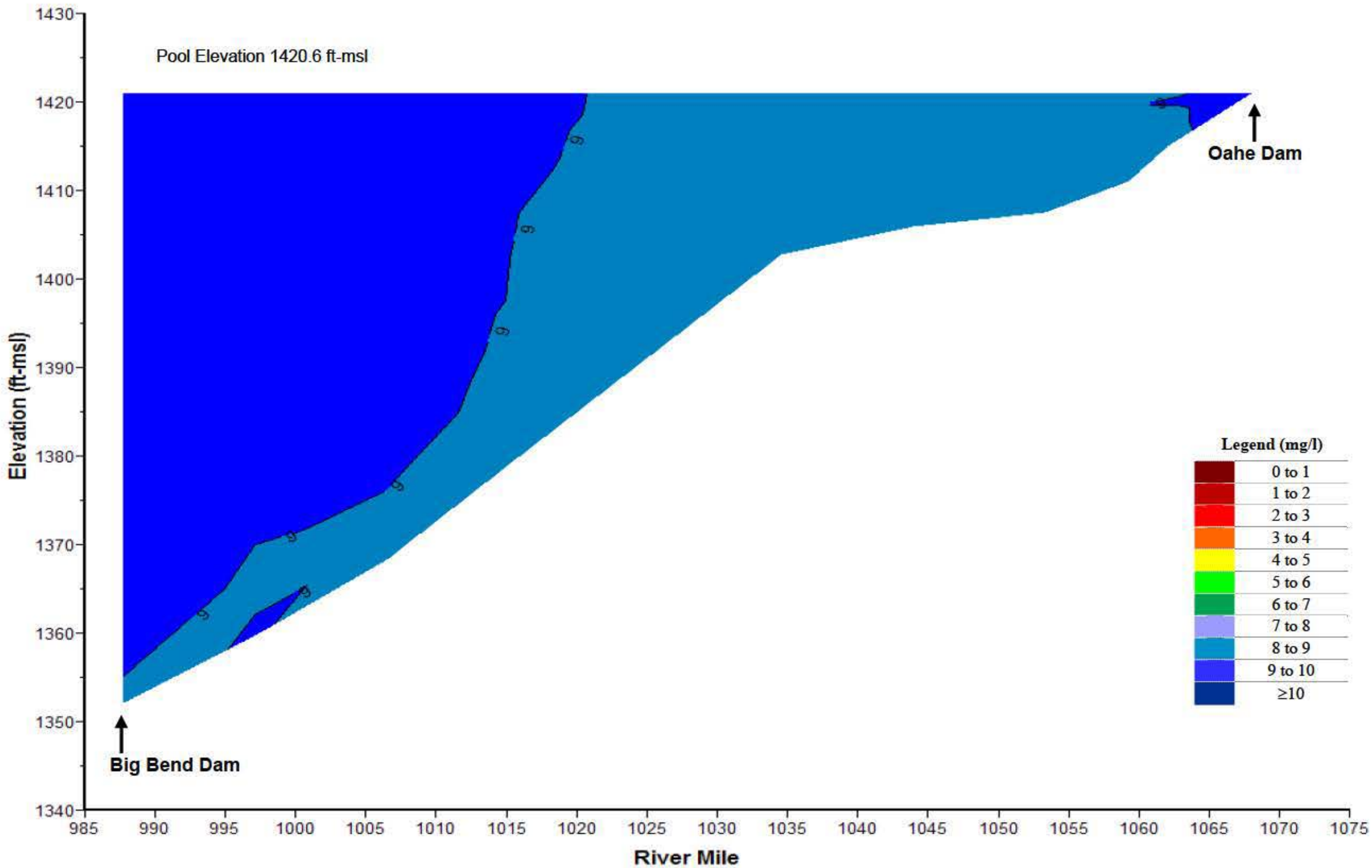


Plate 205. Longitudinal dissolved oxygen (mg/l) contour plot of Big Bend Reservoir based on depth-profile dissolved oxygen concentrations measured at sites BBDLK0987A, BBDLK1004DW, BBDLK1020DW, BBDLK1036DW, BBDLK1055DW and OAHPP1 on June 10, 2008.

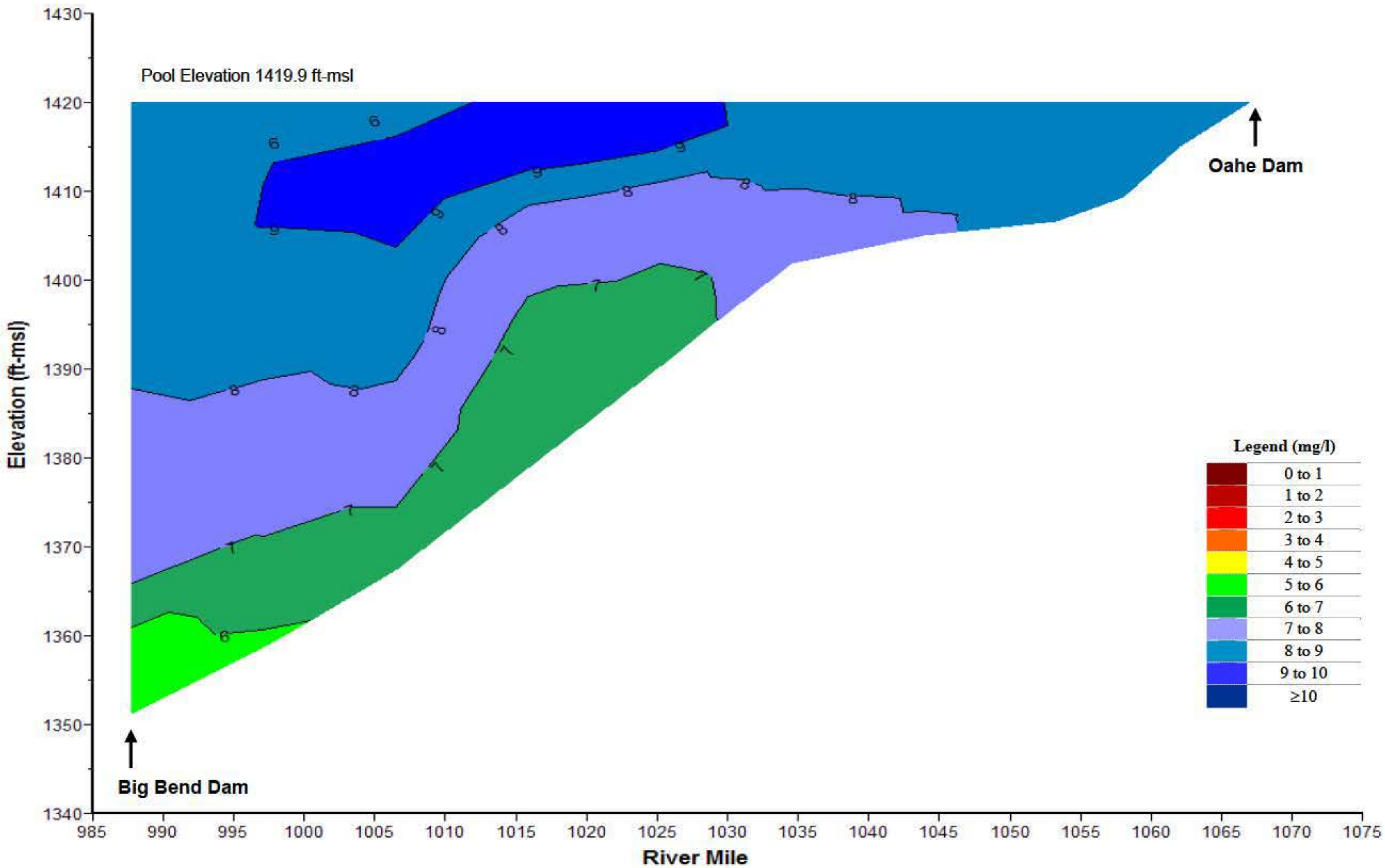


Plate 206. Longitudinal dissolved oxygen (mg/l) contour plot of Big Bend Reservoir based on depth-profile dissolved oxygen concentrations measured at sites BBDLK0987A, BBDLK1004DW, BBDLK1020DW, BBDLK1036DW, BBDLK1055DW and OAHPP1 on July 16, 2008.

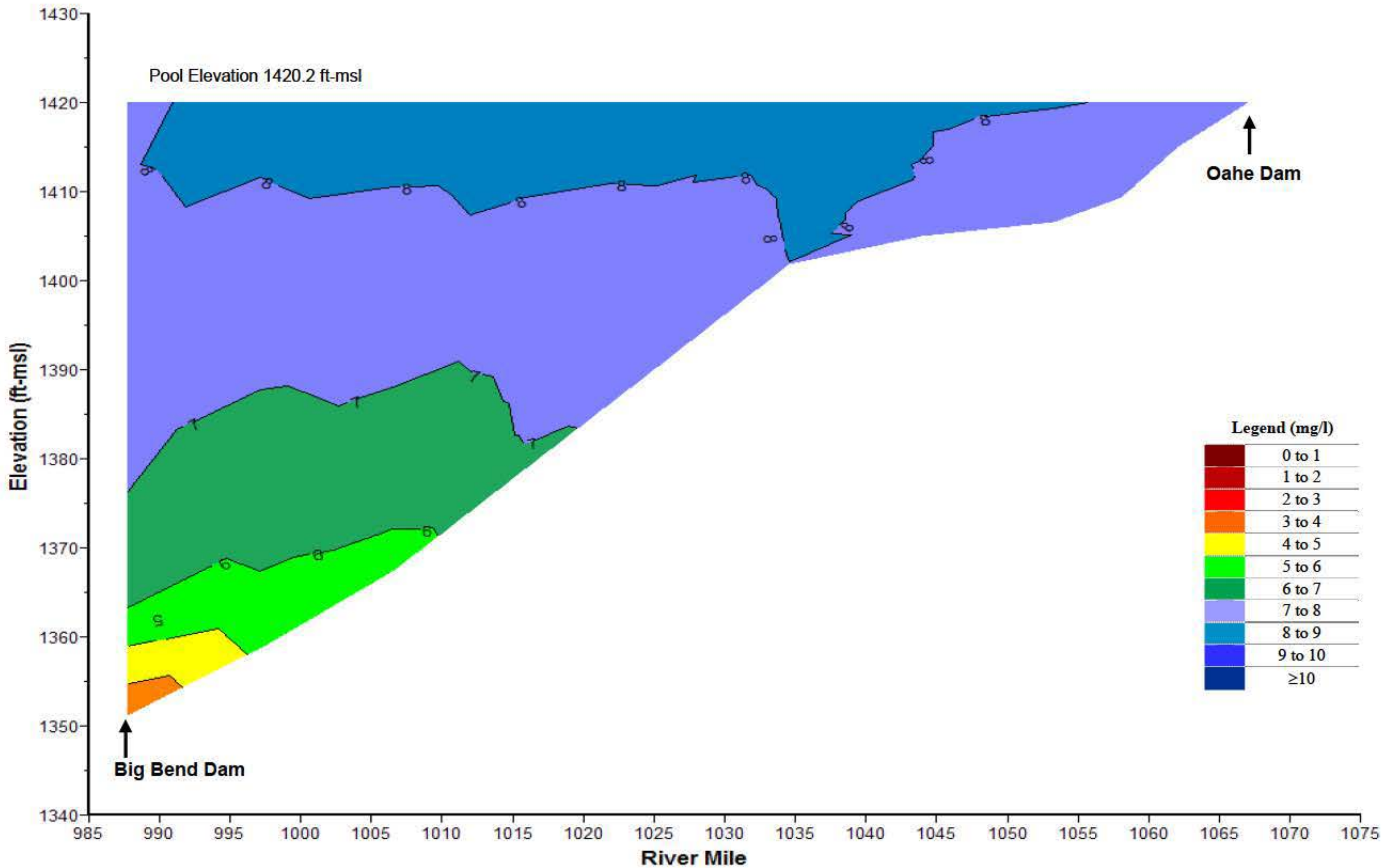


Plate 207. Longitudinal dissolved oxygen (mg/l) contour plot of Big Bend Reservoir based on depth-profile dissolved oxygen concentrations measured at sites BBDLK0987A, BBDLK1004DW, BBDLK1020DW, BBDLK1036DW, BBDLK1055DW and OAHPP1 on August 12, 2008.

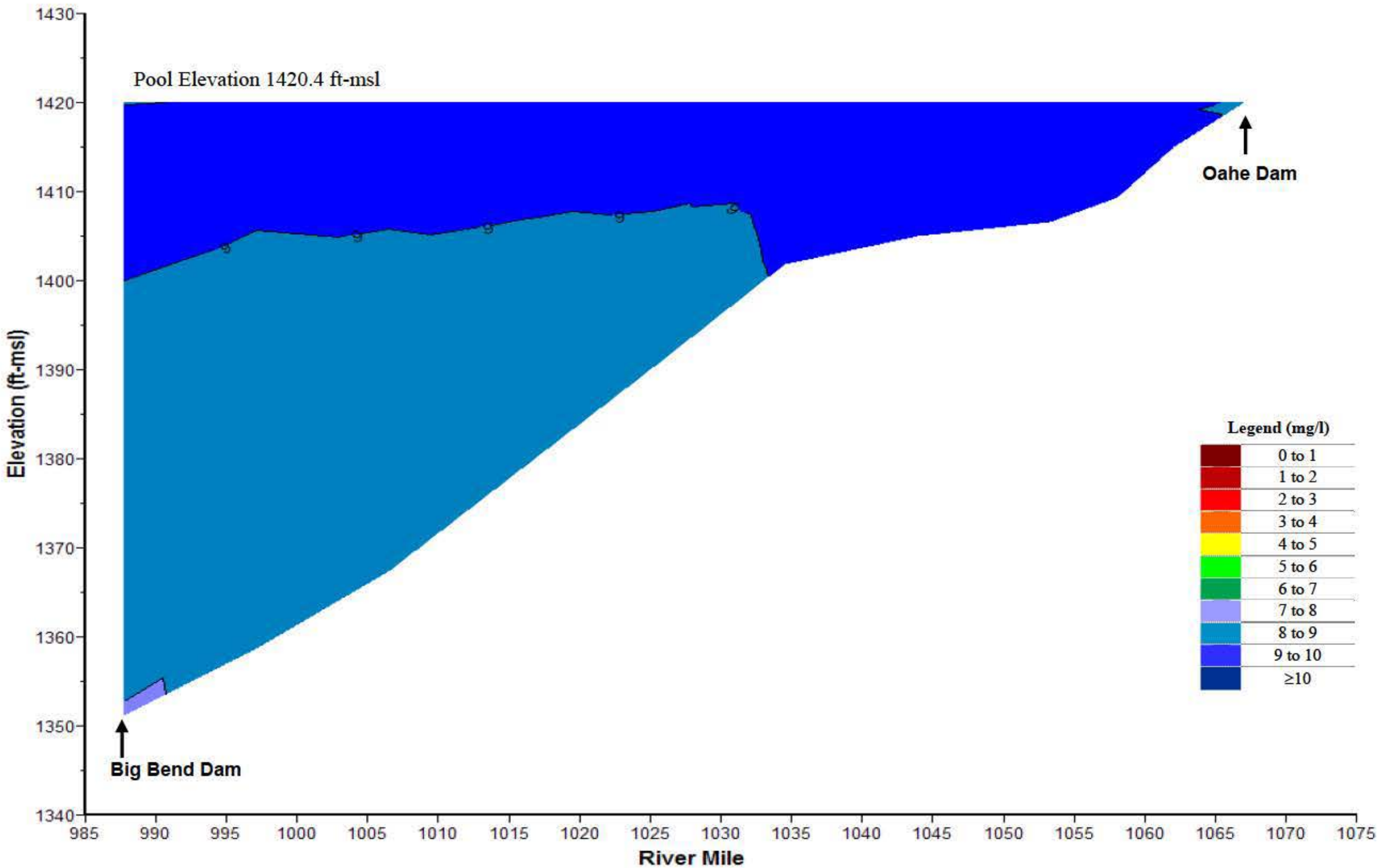


Plate 208. Longitudinal dissolved oxygen (mg/l) contour plot of Big Bend Reservoir based on depth-profile dissolved oxygen concentrations measured at sites BBDLK0987A, BBDLK1004DW, BBDLK1020DW, BBDLK1036DW, BBDLK1055DW and OAHPP1 on September 16, 2008.

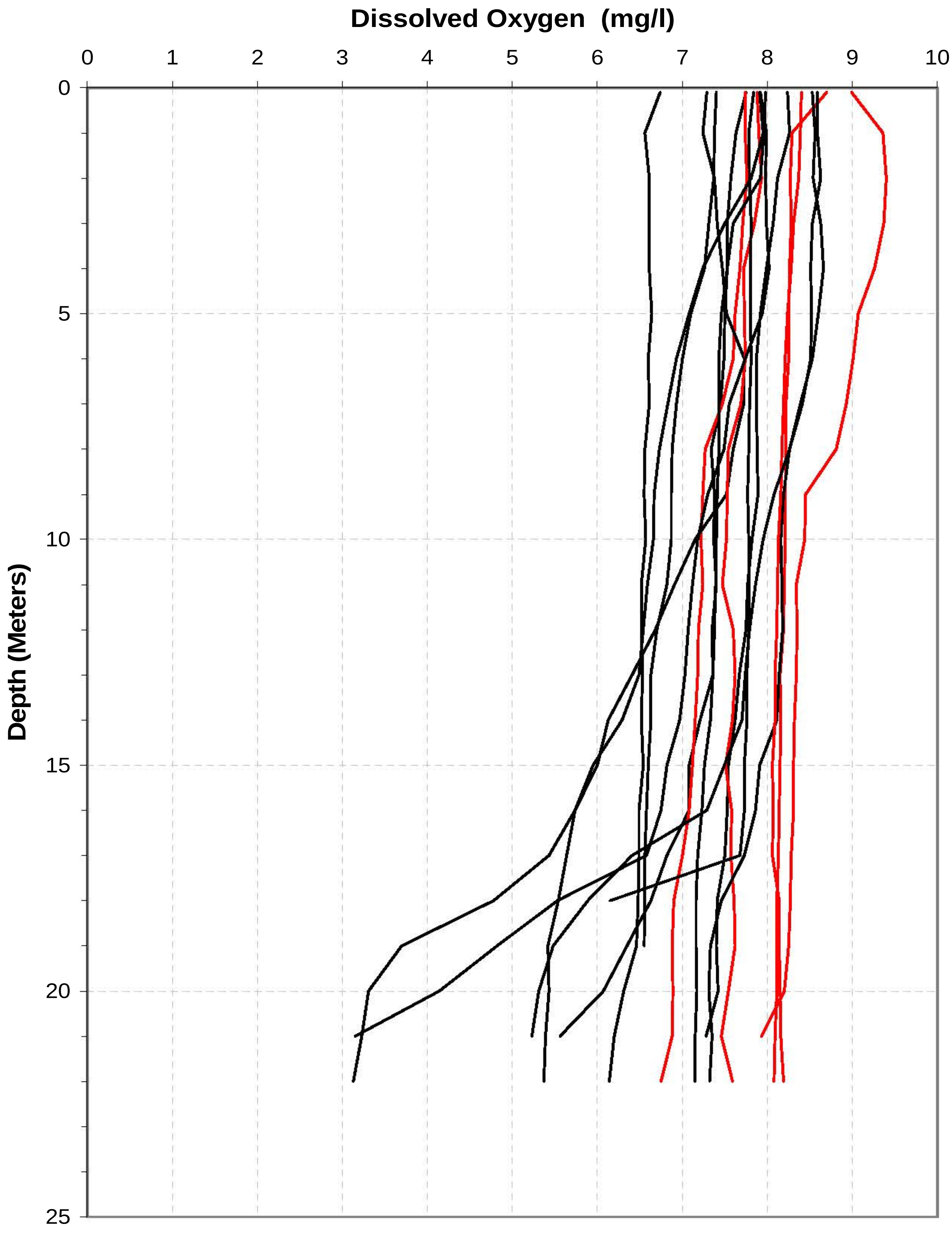


Plate 209. Dissolved oxygen depth profiles for Big Bend Reservoir generated from data collected at the near-dam, deepwater ambient monitoring site during the summer months of the 5-year period of 2004 through 2008.
(Note: Red profile plots were measured in the month of September.)

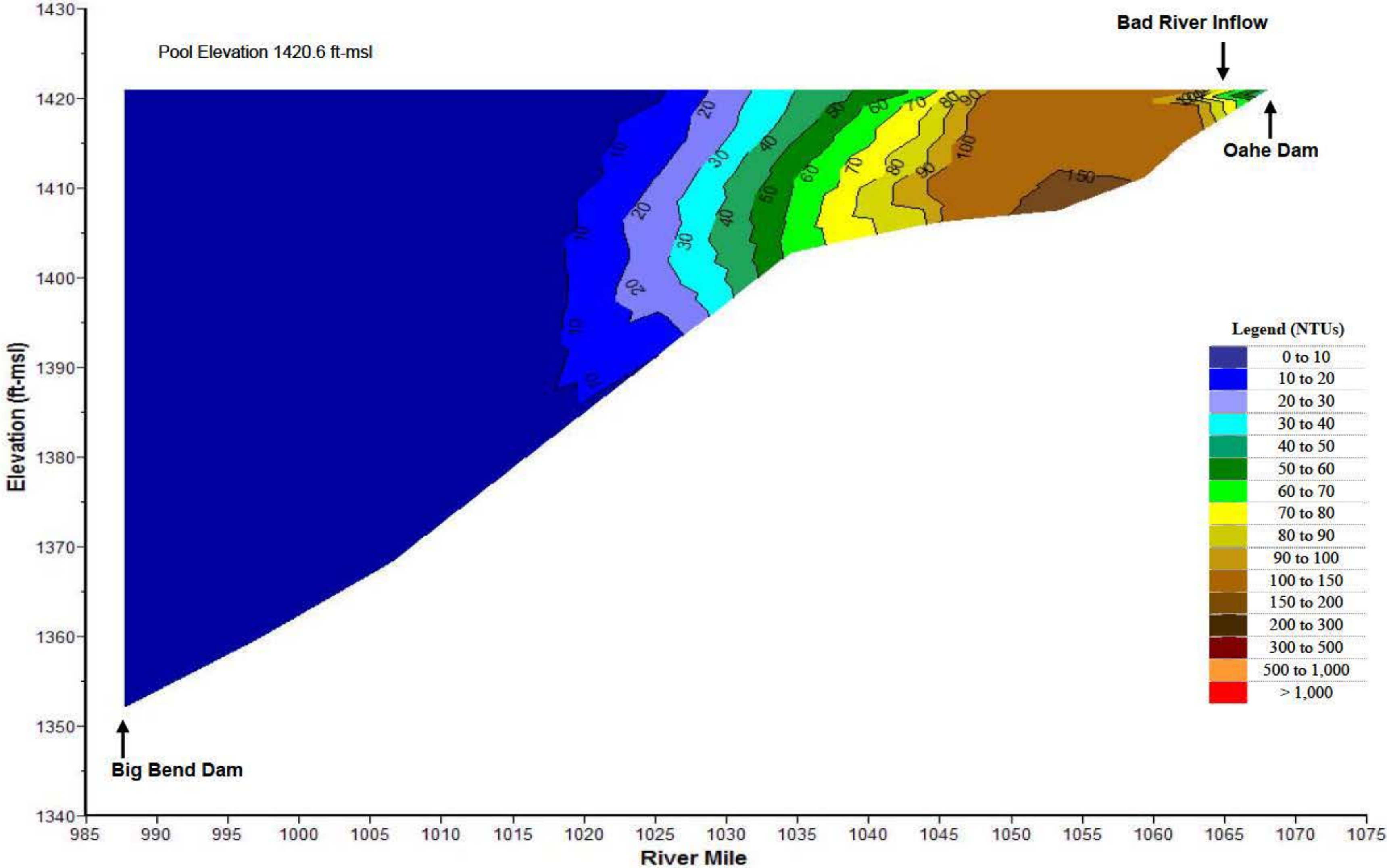


Plate 210. Longitudinal turbidity (NTU) contour plot of Big Bend Reservoir based on depth-profile turbidity levels measured at sites BBDLK0987A, BBDLK1004DW, BBDLK1020DW, BBDLK1036DW, BBDLK1055DW and OAHPP1 on June 10, 2008.

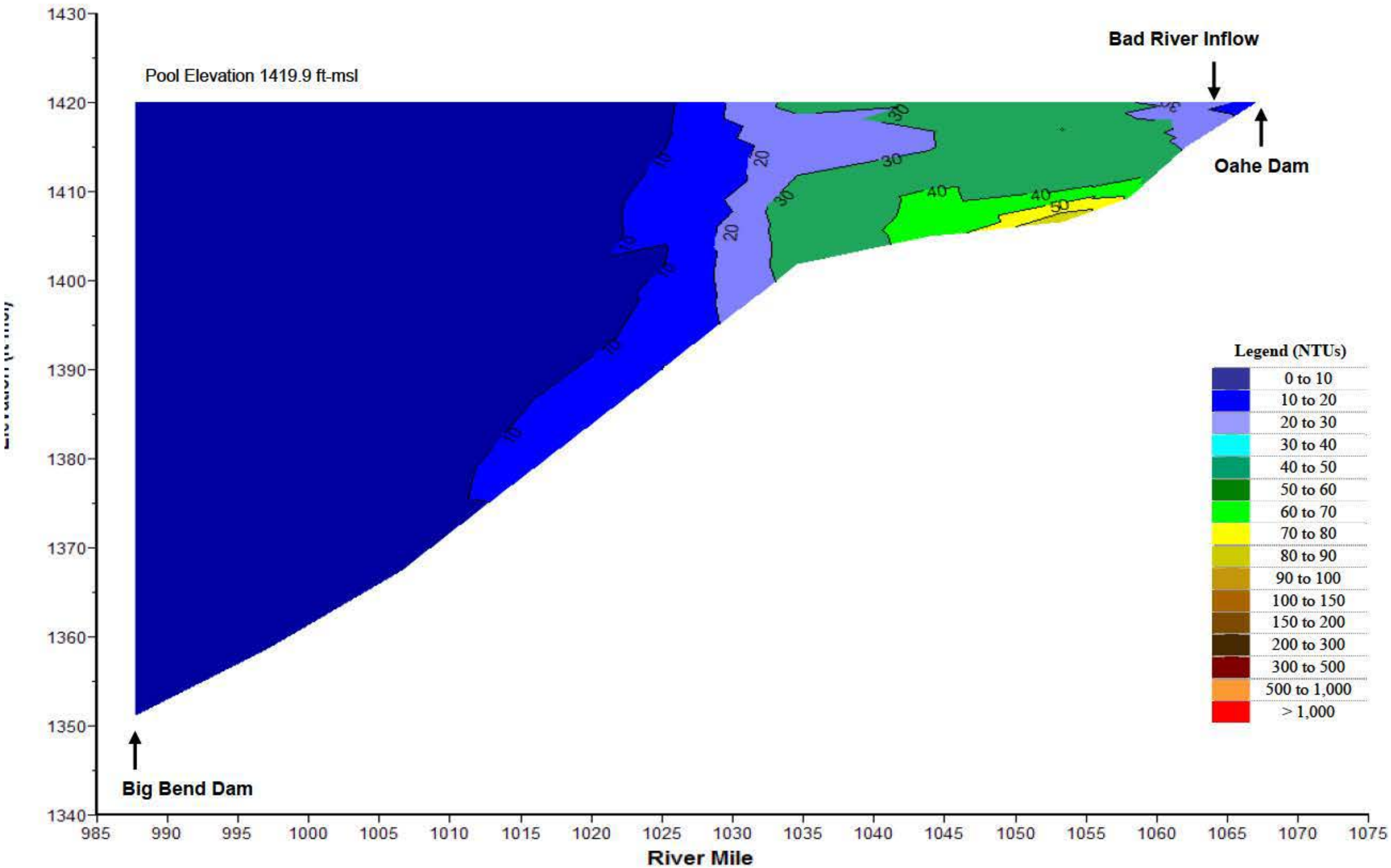


Plate 211. Longitudinal turbidity (NTU) contour plot of Big Bend Reservoir based on depth-profile turbidity levels measured at sites BBDLK0987A, BBDLK1004DW, BBDLK1020DW, BBDLK1036DW, BBDLK1055DW and OAHPP1 on July 16, 2008.

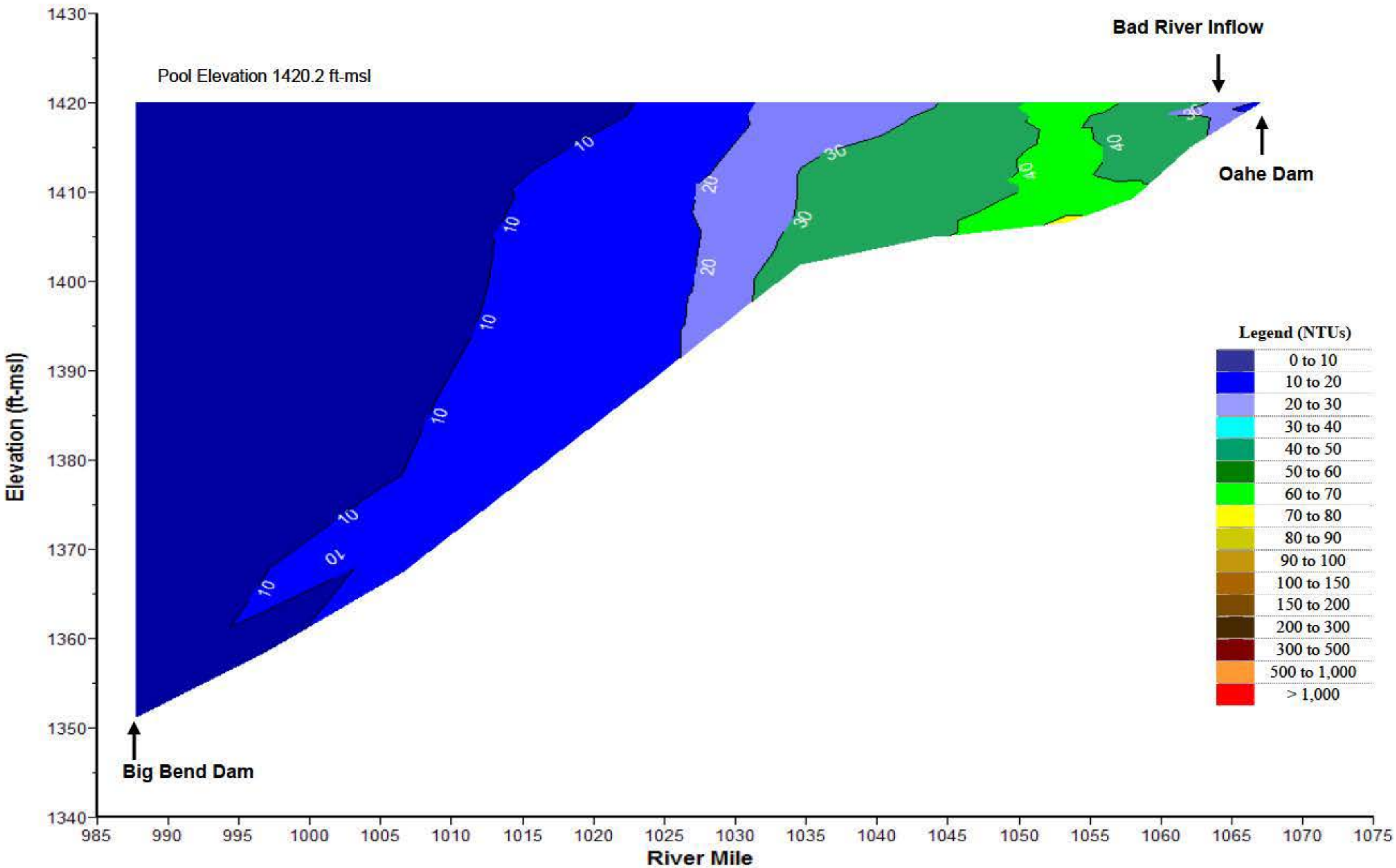


Plate 212. Longitudinal turbidity (NTU) contour plot of Big Bend Reservoir based on depth-profile turbidity levels measured at sites BBDLK0987A, BBDLK1004DW, BBDLK1020DW, BBDLK1036DW, BBDLK1055DW and OAHPP1 on August 12, 2008.

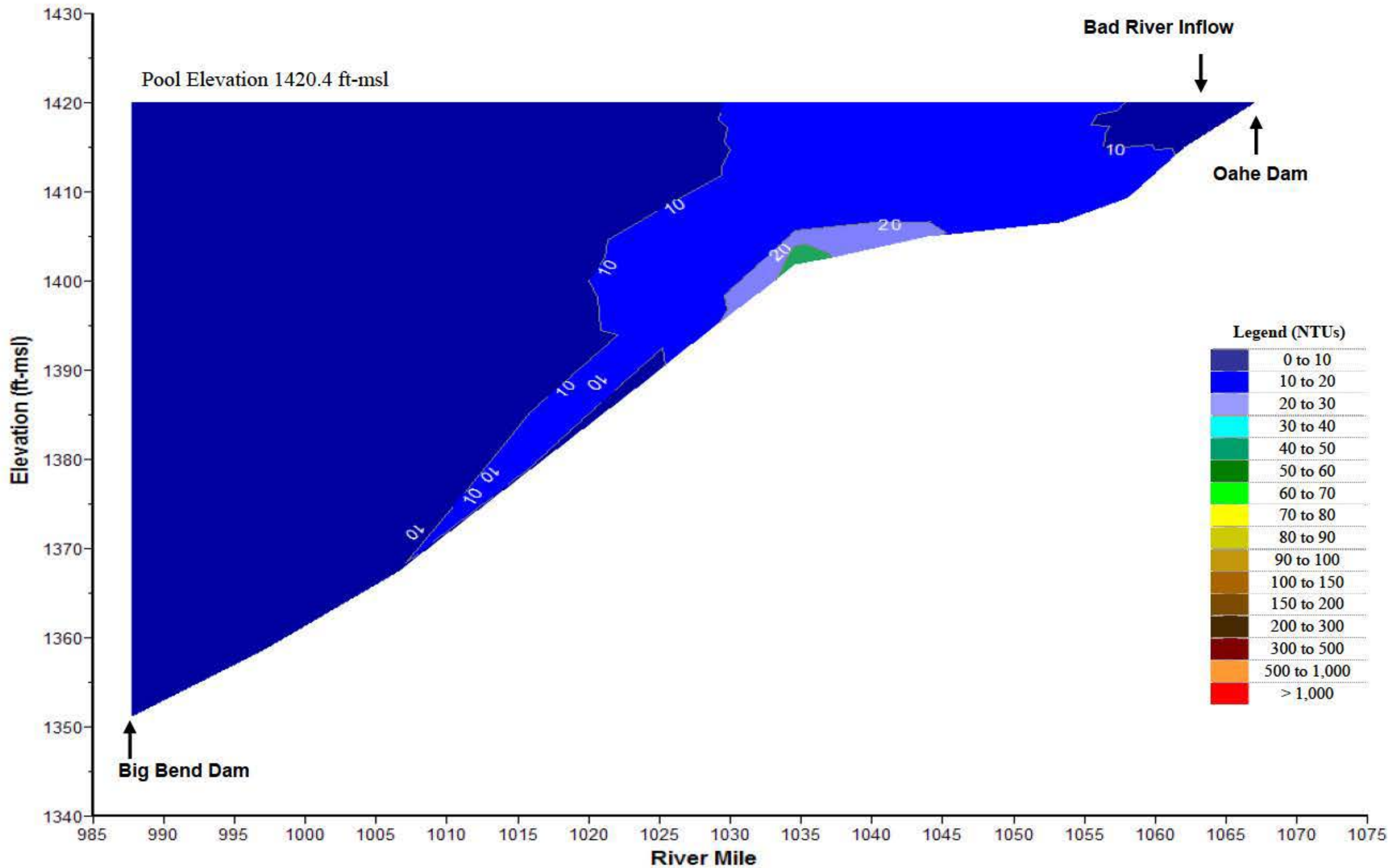


Plate 213. Longitudinal turbidity (NTU) contour plot of Big Bend Reservoir based on depth-profile turbidity levels measured at sites BBDLK0987A, BBDLK1004DW, BBDLK1020DW, BBDLK1036DW, BBDLK1055DW and OAHPP1 on September 16, 2008.

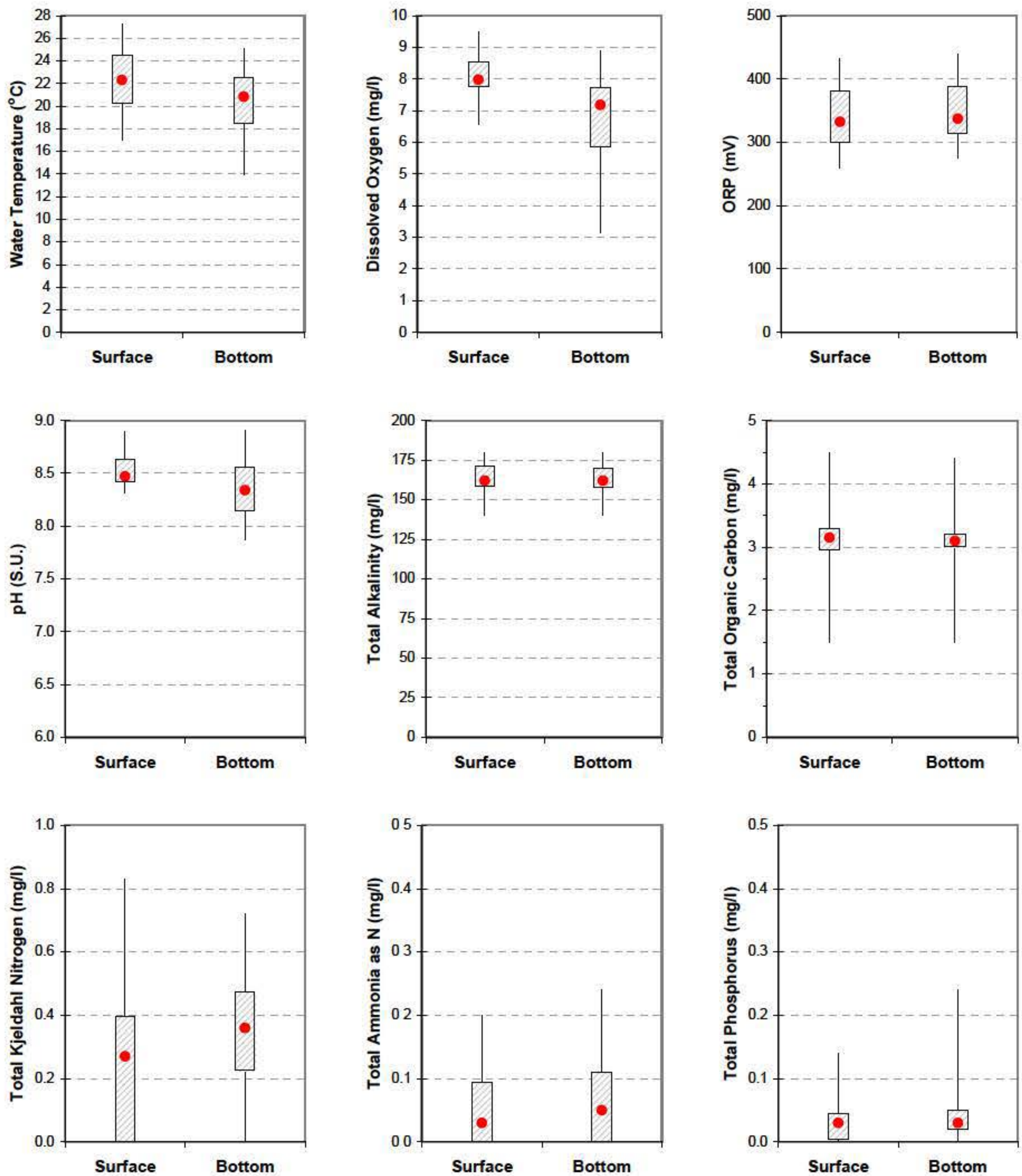


Plate 214. Box plots comparing paired surface and bottom water temperature, dissolved oxygen, oxidation-reduction potential, pH, alkalinity, total organic carbon, total Kjeldahl nitrogen, total ammonia nitrogen, and total phosphorus measurements taken in Big Bend Reservoir at site BBDLK0987A during the summer months of 2004 through 2008.
(Box plots display minimum, 25th percentile, 75th percentile, and maximum. Median value is indicated by the red dot.)

Plate 215. Total biovolume, number of genera present and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected at the near-dam, deepwater ambient monitoring site (i.e., site BBDLK0987A) at Big Bend Reservoir during the 5-year period 2004 through 2008.

Date	Total Sample Biovolume (um^3)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta		Shannon-Weaver Genera Diversity
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	
Jun 2004	6,563,514	3	0.77	0	-----	0	-----	2	0.20	2	0.04	0	-----	0	-----	1.24
Jul 2004	6,337,657	1	0.77	0	-----	0	-----	1	0.03	4	0.20	0	-----	0	-----	0.70
Aug 2004	129,629,728	7	0.79	5	0.05	0	-----	1	0.02	3	<0.01	2	0.13	0	-----	1.15
May 2005	400,458,770	6	0.93	3	<0.01	0	-----	1	0.07	1	<0.01	0	-----	0	-----	1.47
Jun 2005	12,306,159	2	0.26	1	0.04	0	-----	2	0.63	4	0.07	0	-----	0	-----	1.58
Jul 2005	223,854,976	11	0.97	2	0.01	0	-----	0	-----	1	0.01	0	-----	0	-----	1.55
Aug 2005	111,016,029	5	0.22	0	-----	2	0.26	1	0.03	8	0.48	0	-----	0	-----	2.03
Sep 2005	290,622,396	8	0.77	14	0.06	0	-----	1	0.04	5	0.12	2	<0.01	1	<0.01	1.80
May 2006	782,608,177	7	0.97	2	<0.01	0	-----	1	<0.01	0	-----	0	-----	1	0.03	0.93
Jun 2006	569,715,640	7	0.98	8	<0.01	1	<0.01	1	0.02	0	-----	0	-----	0	-----	0.16
Jul 2006	71,040,754	5	0.13	9	0.41	1	<0.01	1	0.16	3	0.14	1	0.16	0	-----	2.33
Aug 2006	460,223,040	13	0.71	14	0.15	1	0.01	1	0.01	5	0.06	3	0.06	1	0.01	2.37
Sep 2006	112,017,227	10	0.51	16	0.25	1	<0.01	1	0.05	7	0.09	2	0.09	1	<0.01	2.68
May 2007	569,470,258	9	0.95	5	0.01	0	-----	1	0.02	1	<0.01	1	0.02	0	-----	0.61
June 2007	517,899,330	5	0.74	9	0.10	1	0.13	1	0.02	1	0.01	0	-----	0	-----	1.00
July 2007	211,432,753	7	0.17	8	0.06	0	-----	2	0.13	4	0.26	1	0.38	0	-----	1.85
Aug 2007	269,806,875	10	0.20	11	0.22	1	0.03	1	0.04	4	0.42	2	0.10	0	----	2.12
Sep 2007	141,864,320	6	0.34	12	0.25	0	-----	1	0.18	7	0.15	1	0.07	0	-----	2.74
May 2008	228,544,365	12	0.97	6	0.01	0	-----	1	0.02	0	-----	1	<0.01	0	-----	1.40
Jun 2008	291,834,051	6	0.87	5	0.01	1	0.09	1	0.02	1	<0.01	1	0.01	0	-----	1.32
Jul 2008	159,849	3	0.83	2	<0.01	1	0.03	1	0.12	2	0.01	0	-----	1	0.01	0.64
Aug 2008	55,130,283	3	0.59	4	0.02	2	0.06	1	0.08	4	0.11	2	0.14	0	-----	1.52
Sep 2008	10,711,939	2	0.08	16	0.55	1	<0.01	2	<0.01	4	<0.01	3	<0.01	0	-----	1.25
Mean	**237,967,308**	**6.4**	**0.63**	**6.6**	**0.11**	**0.6**	**0.06**	**1.1**	**0.09**	**3.1**	**0.11**	**1.0**	**0.09**	**0.2**	**0.01**	**1.50**

* Mean percent composition represents the mean when taxa of that division are present.

Plate 216. Total biovolume, number of genera present and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected at the mid-lake site (i.e., site BBDLK1020DW) at Big Bend Reservoir during 2008.

Date	Total Sample Biovolume (um^3)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta		Shannon-Weaver Genera Diversity
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	
Jun 2008	112,139,548	10	0.88	6	0.01	1	0.01	1	0.10	1	<0.01	0	-----	0	-----	1.61
Jul 2008	144,885	3	0.46	6	0.05	1	0.08	1	0.30	3	0.02	2	0.06	2	0.02	1.71
Aug 2008	120,710,561	7	0.41	13	0.14	0	-----	1	0.25	7	0.02	2	0.08	2	0 10	2.07
Sep 2008	55,048,141	7	0.41	6	0.21	0	-----	2	0.37	1	<0.01	1	<0.01	0	-----	1.77
Mean	**72,010,784**	**6.8**	**0.54**	**7.8**	**0.10**	**0.5**	**0.05**	**1.3**	**0.26**	**3.0**	**0.01**	**1.3**	**0.05**	**1.0**	**0.06**	**1.79**

* Mean percent composition represents the mean when taxa of that division are present.

Plate 217. Total biovolume, number of genera present and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected in the upstream reaches of Big Bend Reservoir (i.e., site BBDLK1055DW) during 2008.

Date	Total Sample Biovolume (um^3)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta		Shannon-Weaver Genera Diversity
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	
Jun 2008	111,255,352	13	0 96	0	-----	0	-----	1	0.04	0	-----	0	-----	0	-----	2.03
Jul 2008	63,807	7	0.27	4	0.04	1	0.05	1	0.45	0	-----	2	0.18	0	-----	1.57
Aug 2008	43,271,250	9	0.82	1	0.01	1	0.06	1	0.05	2	<0.01	1	0.06	0	-----	1.56
Sep 2008	204,098,336	13	0.86	3	0.02	0	-----	2	0.02	2	0.01	1	0.09	0	-----	1.57
Mean	**89,672,186**	**10.5**	**0.73**	**2.0**	**0.02**	**0.5**	**0.06**	**1.3**	**0.14**	**1.0**	**0.01**	**1.0**	**0.11**	**0**	**-----**	**1.68**

* Mean percent composition represents the mean when taxa of that division are present.

Plate 218. Dominant taxa present in phytoplankton grab samples collected at the near-dam monitoring site (site BBDLK0987A) at Big Bend Reservoir during the 5-year period 2004 through 2008.

Date	Division	Dominant Taxa*	Percent of Total Biovolume
June 2004	Bacillariophyta	*Asterionella formossa*	0.61
	Bacillariophyta	*Navicula spp.*	0.14
	Cryptophyta	*Rhodomonas minuta*	0.13
July 2004	Bacillariophyta	*Asterionella formossa*	0.77
	Cyanobacteria	*Anabaena spp.*	0.13
August 2004	Bacillariophyta	*Fragilaria crotonensis*	0.70
	Pyrrophyta	*Ceratium hirundinella*	0.13
May 2005	Bacillariophyta	*Fragilaria crotonensis*	0.36
	Bacillariophyta	*Tabellaria fenestrata*	0.29
	Bacillariophyta	*Asterionella formossa*	0.23
June 2005	Cryptophyta	*Rhodomonas minuta*	0.37
	Cryptophyta	*Cryptomonas spp.*	0.26
	Bacillariophyta	*Stephanodiscus spp.*	0.22
July 2005	Bacillariophyta	*Fragilaria crotonensis*	0.45
	Bacillariophyta	*Asterionella formossa*	0.31
August 2005	Cyanobacteria	*Pseudanabaena limnetica*	0.33
	Chrysophyta	*Dinobryon sertularia*	0.24
September 2005	Bacillariophyta	*Stephanodiscus hantzschii*	0.56
May 2006	Bacillariophyta	*Asterionella formossa*	0.48
	Bacillariophyta	*Fragilaria crotonensis*	0.45
June 2006	Bacillariophyta	*Fragilaria spp.*	0.97
July 2006	Pyrrophyta	*Ceratium hirundinella*	0.16
	Cryptophyta	*Rhodomonas minuta*	0.16
	Chlorophyta	*Cosmarium spp.*	0.16
	Cyanobacteria	*Gomphosphaeria aponina*	0.13
August 2006	Bacillariophyta	*Stephanodiscus hantzschii*	0.41
September 2006	Bacillariophyta	*Cyclotella spp.*	0.31
May 2007	Bacillariophyta	*Fragilaria spp.*	0.87
June 2007	Bacillariophyta	*Fragilaria spp.*	0.73
	Chrysophyta	*Dinobryon spp.*	0.13
July 2007	Pyrrophyta	*Ceratium hirundinella*	0.38
	Cyanobacteria	*Anabaena spp.*	0.25
	Cryptophyta	*Rhodomonas spp.*	0.12
August 2007	Cyanobacteria	*Dactylococcopsis acicularis*	0.41
	Chlorophyta	*Pediastrum duplex var. clathratum*	0.16
September 2007	Cryptophyta	*Rhodomonas spp.*	0.18
	Bacillariophyta	*Fragilaria spp.*	0.11
May 2008	Bacillariophyta	*Tabellaria flocculosa*	0.35
	Bacillariophyta	*Asterionella formossa*	0.28
	Bacillariophyta	*Fragilaria crotonensis*	0.28
June 2008	Bacillariophyta	*Fragilaria crotonensis*	0.56
	Bacillariophyta	*Tabellaria flocculosa*	0.17
	Bacillariophyta	*Asterionella formossa*	0.14

Plate 218. (Continued).

Date	Division	Dominant Taxa*	Percent of Total Biovolume
July 2008	Bacillariophyta	*Fragilaria crotonensis*	0.83
	Cryptophyta	*Rhodomonas minuta*	0.12
August 2008	Bacillariophyta	*Fragilaria crotonensis*	0.55
	Pyrrophyta	*Ceratium hirundinella*	0.14
September 2008	Chlorophyta	*Crucigenia quadrata*	0.33
	Chlorophyta	*Cosmarium spp.*	0.24
	Chlorophyta	*Chlamydomonas spp.*	0.16
	Chlorophyta	*Closterium spp.*	0.13

* Dominant taxa are genera or species (depending on identification level) that comprised more than 10% of the total sample biovolume.

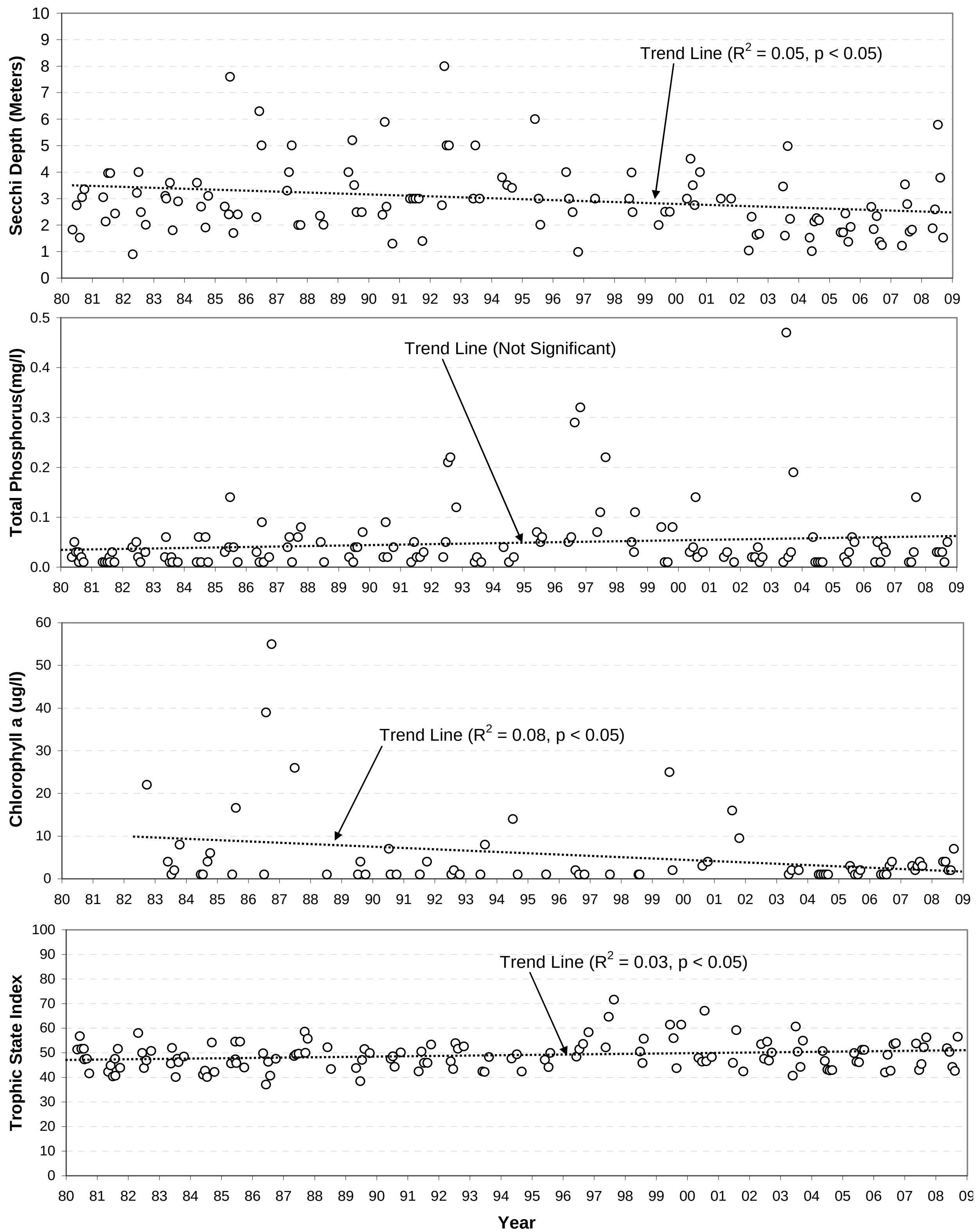


Plate 219. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and Trophic State Index (TSI) monitored in Big Bend Reservoir at the near-dam, ambient site (i.e., site BBDLK0987A) over the 29-year period of 1980 through 2008.

Plate 220. Summary of water quality conditions monitored in the Bad River at site BBDNFBADR1 during 2008.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit(A)	No. of Obs.	Mean(B)	Median	Min.	Max.	State WQS Criteria(C)	No. of WQS Exceedences	Percent WQS Exceedence
Flow (cfs)	1	5	761.6	6.1	0.2	3,760.0	-----	-----	-----
Water Temperature (C)	0.1	3	22.6	23.2	20.1	24.6	27(1,4)	0	0%
Dissolved Oxygen (mg/l)	0.1	3	10.9	8.9	6.8	17.0	5(1,5)	1	2%
Dissolved Oxygen (% Sat.)	0.1	3	111.5	111.0	78.2	145.2	-----	-----	-----
pH (S.U.)	0.1	3	8.0	8.0	7.9	8.2	6 5(1,2,5), 9.0(1,2,4), 9 5(3,4)	0	0%
Specific Conductance (umho/cm)	1	3	1,069	1,084	378	1,745	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	3	380	319	268	552	-----	-----	-----
Turbidity (NTU)	1	4	357	30	7	1,359	-----	-----	-----
Alkalinity, Total (mg/l)	7	5	147	159	116	165	-----	-----	-----
Ammonia, Total (mg/l)	0.02	5	-----	n.d.	n.d.	0 34	8.4 (1,4,7), 1.4(1,6,7)	0	0%
Carbon, Total Organic (mg/l)	0.05	5	6.6	6.0	2.9	10.8	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	5	30	24	6	82	-----	-----	-----
Chloride, Dissolved (mg/l)	1	5	30	26	9	74	175(1,4), 100(1,6), 438(2,4), 250(2,6)	0	0%
Dissolved Solids, Total (mg/l)	5	5	739	710	460	1,226	1,750(2,4), 1,000(2,7), 3,500(3,4), 2,000(3,6)	0, 1, 0, 0	0%, 20%, 0%, 0%
Iron, Total (ug/l)	40	4	23,825	995	310	93,000	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	5	1.2	0.9	0.3	3.3	-----	-----	-----
Manganese, Total (ug/l)	2	4	1,317	90	30	5,060	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	5	-----	n.d.	n.d.	0.40	10(2,4)	0	0%
Phosphorus, Dissolved (mg/l)	0.02	5	0.03	0.03	n.d.	0.05	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	5	0.64	0.09	0.04	2.90	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	5	-----	n.d.	n.d.	0.05	-----	-----	-----
Sulfate (mg/l)	1	5	335	335	135	630	875(2,4), 500(2,6)	0, 1	0%, 20%
Suspended Solids, Total (mg/l)	4	5	719	29	n.d.	3,478	158(1,4), 90(1,6)	1, 1	20%, 20%
Pesticide Scan (ug/l)(D)	0.05	1	-----	n.d.	n.d.	n.d.	-----	-----	-----

n.d. = Not detected, b.d. = Criterion below detection limit.

(A) Detection limits given for the parameters Stream Flow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for the protection of warmwater permanent fish life propagation waters.
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of commerce and industry waters.
- (4) Daily maximum criterion (monitoring results directly comparable to criterion).
- (5) Daily minimum criterion (monitoring results directly comparable to criterion).
- (6) 30-day average criterion (monitoring results not directly comparable to criterion).
- (7) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

(D) The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, cycloate, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, isopropalin, metolachlor, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, phorate, profluralin, prometon, propachlor, propazine, simazine, terbufos, triallate, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

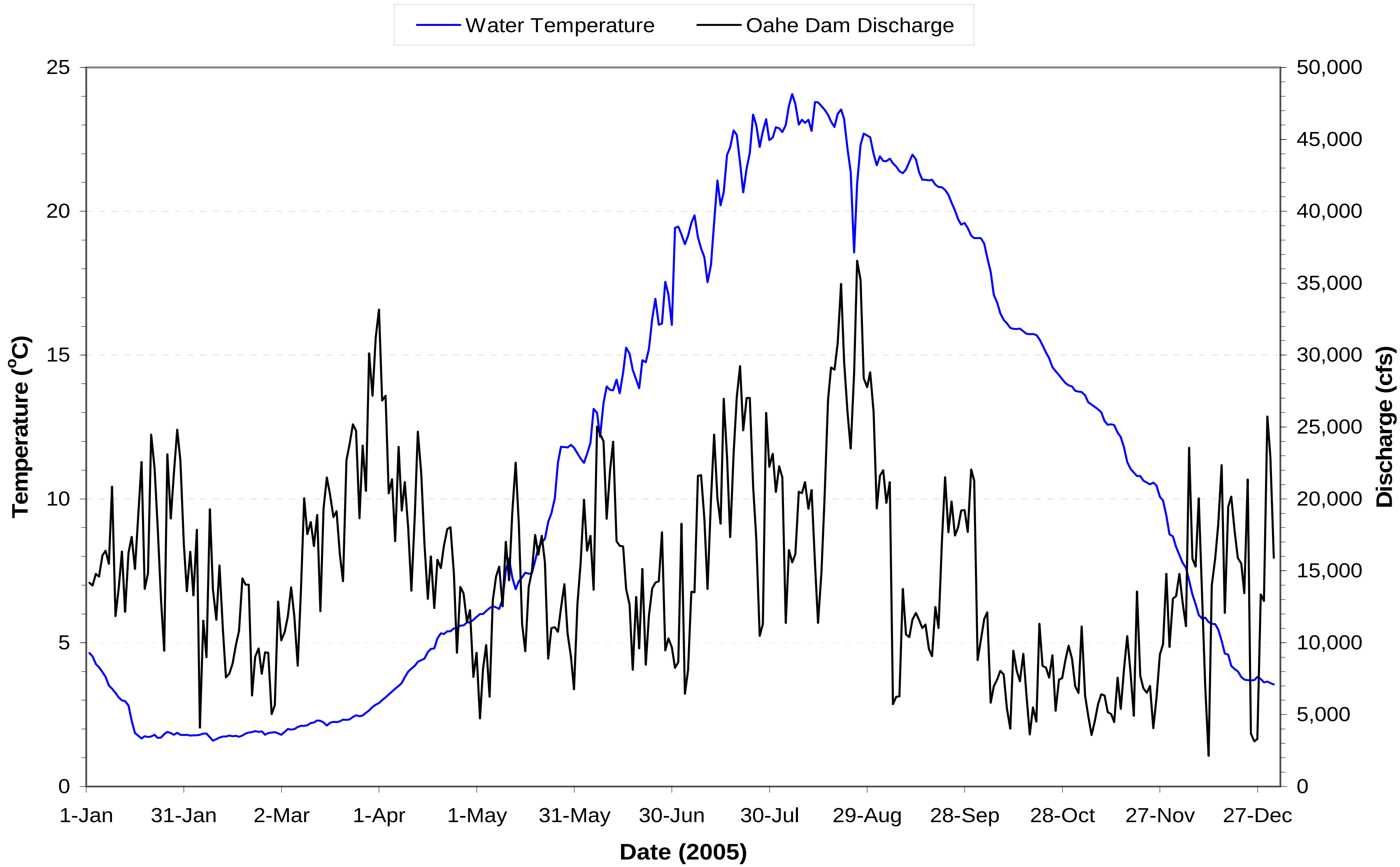


Plate 221. Mean daily water temperature and discharge of the Missouri River at Oahe Dam (i.e., site OAHPP1) for 2005. Mean daily temperatures and discharges based on hourly measurements recorded on discharge through Oahe Dam.

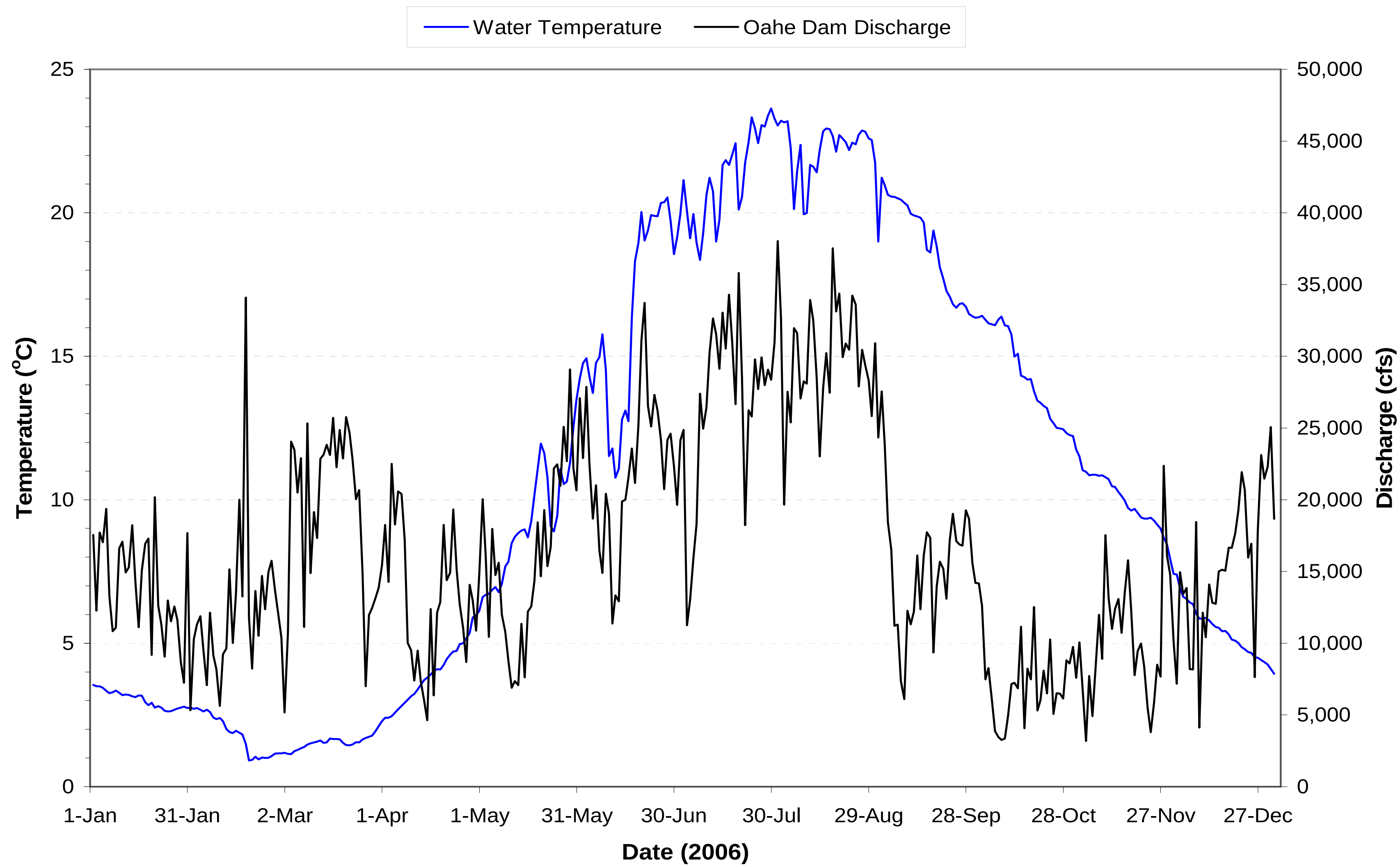


Plate 222. Mean daily water temperature and discharge of the Missouri River at Oahe Dam (i.e., site OAHPP1) for 2006. Mean daily temperatures and discharges based on hourly measurements recorded on discharge through Oahe Dam.

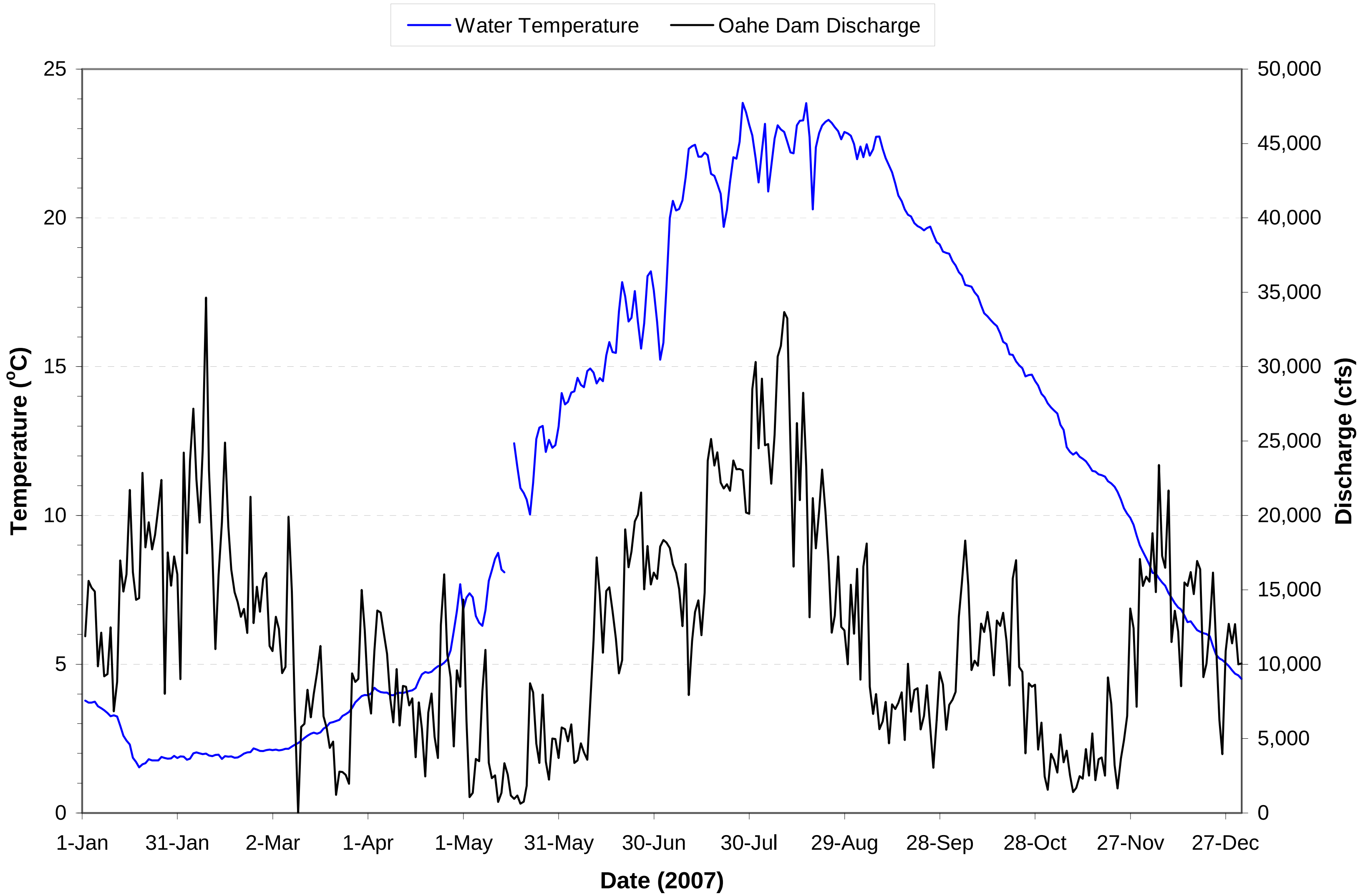


Plate 223. Mean daily water temperature and discharge of the Missouri River at Oahe Dam (i.e., site OAHPP1) for 2007. Mean daily temperatures and discharges based on hourly measurements recorded on discharge through Oahe Dam.

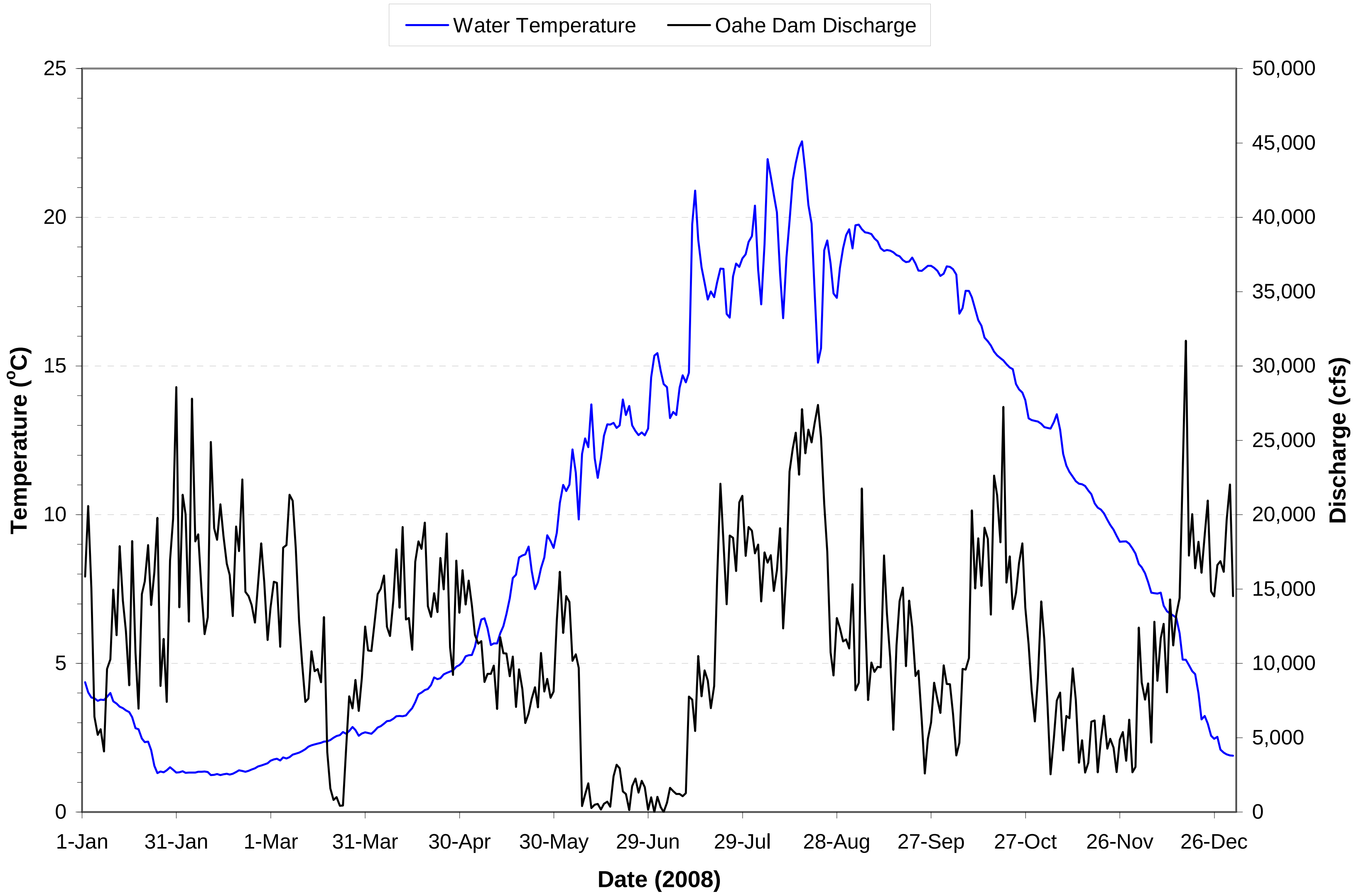


Plate 224. Mean daily water temperature and discharge of the Missouri River at Oahe Dam (i.e., site OAHPP1) for 2008. Mean daily temperatures and discharges based on hourly measurements recorded on discharge through Oahe Dam.

Plate 225. Summary of water quality conditions monitored on water discharged through Big Bend Dam (i.e., site BBDPP1) during the 5-year period of 2004 through 2008.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit[A]	No. of Obs.	Mean[B]	Median	Min.	Max.	State WQS Criteria[C]	No. of WQS Exceedences	Percent WQS Exceedence
Dam Discharge (cfs)	1	47	23,566	23,00	0	71,980	-----	-----	-----
Water Temperature (C)	0.1	44	12.8	13.4	0.5	25.4	27[1,4]	0	0%
Dissolved Oxygen (mg/l)	0.1	43	9.4	9.3	3.8	13.5	5[1,5]	1	2%
Dissolved Oxygen (% Sat.)	0.1	43	89.7	92.4	44.7	105.5	-----	-----	-----
pH (S.U.)	0.1	42	8.3	8.3	7.6	8.7	6 5[1,2,5], 9.0[1,2,4], 9 5[3,4]	0	0%
Specific Conductance (umho/cm)	1	43	675	690	500	739	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	22	361	361	243	444	-----	-----	-----
Turbidity (NTU)	1	22	12	3	n.d.	60	-----	-----	-----
Alkalinity, Total (mg/l)	7	47	170	167	140	206	-----	-----	-----
Ammonia, Total (mg/l)	0.02	47	-----	0.04	n.d.	0 31	4.7 [1,4,7], 1.4 [1,6,7]	0	0%
Carbon, Total Organic (mg/l)	0.05	46	3.2	3.1	1.5	5.6	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	31	10	10	n.d.	21	-----	-----	-----
Chloride, Dissolved (mg/l)	1	29	12	11	9	25	175[1,4], 100[1,6], 438[2,4], 250[2,6]	0	0%
Dissolved Solids, Total (mg/l)	5	47	471	470	379	753	1,750[2,4], 1,000[2,7], 3,500[3,4], 2,000[3,6]	0	0%
Hardness, Total (mg/l)	0.4	3	201	205	169	228	-----	-----	-----
Iron, Total (ug/l)	40	30	218	157	n.d.	688	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	47	0.5	0.4	n.d.	1.7	-----	-----	-----
Manganese, Total (ug/l)	2	30	55	42	n.d.	178	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	47	-----	n.d.	n.d.	0.40	10[2,4]	0	0%
Phosphorus, Dissolved (mg/l)	0.02	29	-----	n.d.	n.d.	0.07	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	47	-----	0.03	n.d.	0 30	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	45	-----	n.d.	n.d.	0.04	-----	-----	-----
Sulfate (mg/l)	1	47	199	200	119	230	875[2,4], 500[2,6]	0	0%
Suspended Solids, Total (mg/l)	4	47	-----	n.d.	n.d.	57	158[1,4], 90[1,6]	0	0%
Aluminum, Dissolved (ug/l)	25	3	-----	n.d.	n.d.	n.d.	-----	-----	-----
Antimony, Dissolved (ug/l)	0.5	2	-----	n.d.	n.d.	0.6	5.6[10]	0	0%
Arsenic, Dissolved (ug/l)	1	7	-----	n.d.	n.d.	2	340[8], 150[9], 0.018[10]	0, 0, b.d.	0%, 0%, b.d.
Barium, Dissolved (ug/l)	5	2	43	43	41	44	-----	-----	-----
Beryllium, Dissolved (ug/l)	2	4	-----	n.d.	n.d.	n.d.	4[10]	0	0%
Cadmium, Dissolved (ug/l)	0.2	7	-----	n.d.	n.d.	n.d.	4.0[8], 0.40[9], 5[10]	0	0%
Chromium, Dissolved (ug/l)	10	7	-----	n.d.	n.d.	n.d.	1,026[8], 133[9]	0	0%
Copper, Dissolved (ug/l)	2	7	-----	n.d.	n.d.	n.d.	26[8], 17[9], 1,300[10]	0	0%
Lead, Dissolved (ug/l)	0.5	7	-----	n.d.	n.d.	n.d.	140[8], 5.5[9]	0	0%
Mercury, Dissolved (ug/l)	0.02	8	-----	n.d.	n.d.	n.d.	1.7[8], 0.05[10]	0	0%
Mercury, Total (ug/l)	0.02	8	-----	n.d.	n.d.	n.d.	0.77[9]	0	0%
Nickel, Dissolved (ug/l)	10	7	-----	n.d.	n.d.	n.d.	859[8], 95[9], 610[10]	0	0%
Selenium, Total (ug/l)	1	5	-----	n.d.	n.d.	n.d.	-----	-----	-----
Silver, Dissolved (ug/l)	1	7	-----	n.d.	n.d.	n.d.	11[8]	0	0%
Thallium, Total (ug/l)	0.5	4	-----	n.d.	n.d.	n.d.	0.24[10]	b.d.	b.d.
Zinc, Total (ug/l)	10	7	-----	10	n.d.	11	215[8,9], 7,400[10]	0	0%
Pesticide Scan (ug/l)[D]	0.05	5	-----	n.d.	n.d.	n.d.	-----	-----	-----

n.d. = Not detected, b.d. = Criterion below detection limit.

[A] Detection limits given for the parameters Stream Flow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

[B] Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

[C] Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- [1] Criteria for the protection of warmwater permanent fish life propagation waters.
- [2] Criteria for the protection of domestic water supply waters.
- [3] Criteria for the protection of commerce and industry waters.
- [4] Daily maximum criterion (monitoring results directly comparable to criterion).
- [5] Daily minimum criterion (monitoring results directly comparable to criterion).
- [6] 30-day average criterion (monitoring results not directly comparable to criterion).
- [7] Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- [8] Acute (CMC) criterion for the protection of freshwater aquatic life.
- [9] Chronic (CCC) criterion for the protection of freshwater aquatic life.
- [10] Criterion for the protection of human health.

Note: Some of South Dakota's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

[D] The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, cycloate, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, isopropalin, metolachlor, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, phorate, profluralin, prometon, propachlor, propazine, simazine, terbufos, triallate, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

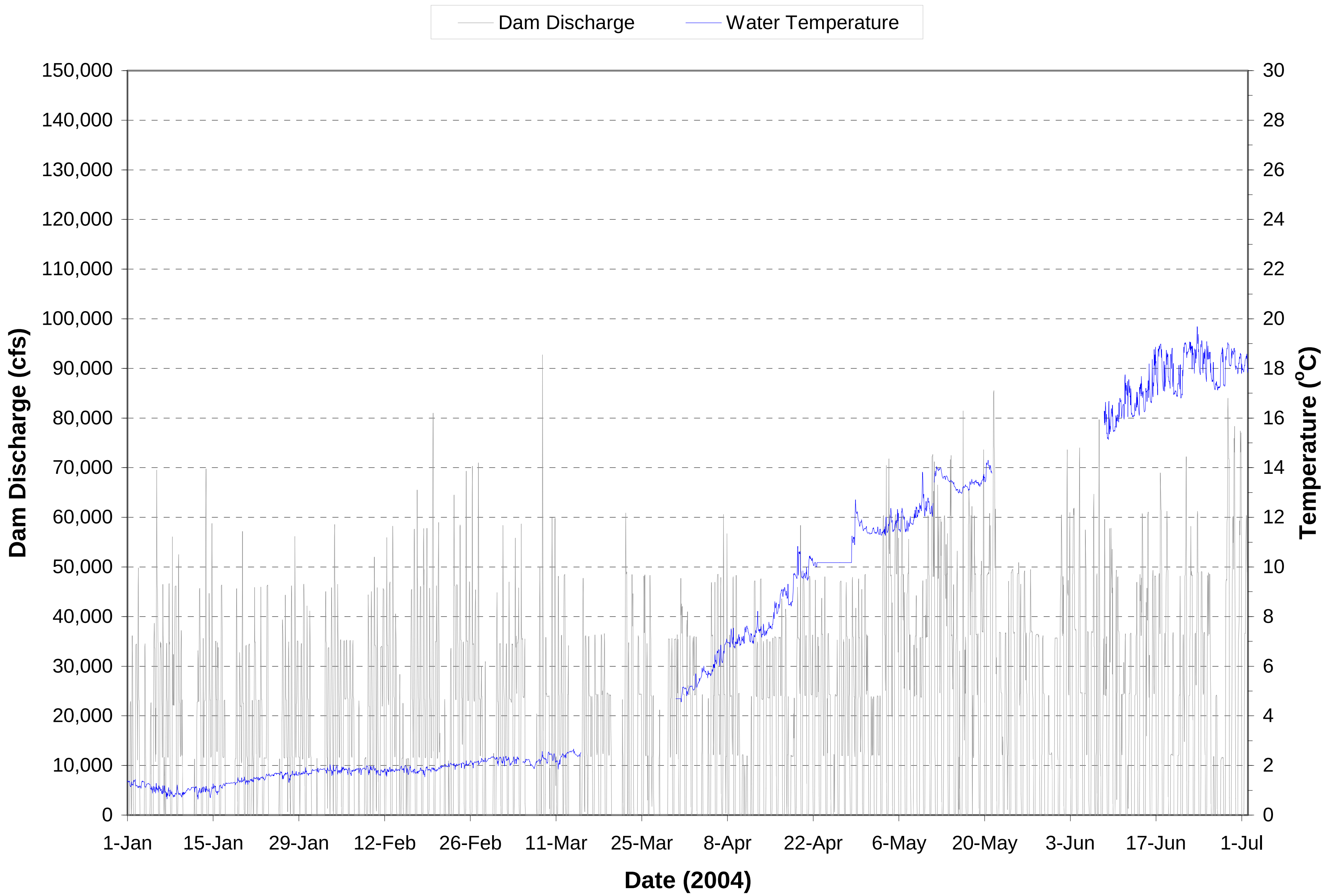


Plate 226. Hourly discharge and water temperature monitored at the Big Bend powerplant on water discharged through the dam during the period January through June 2004.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

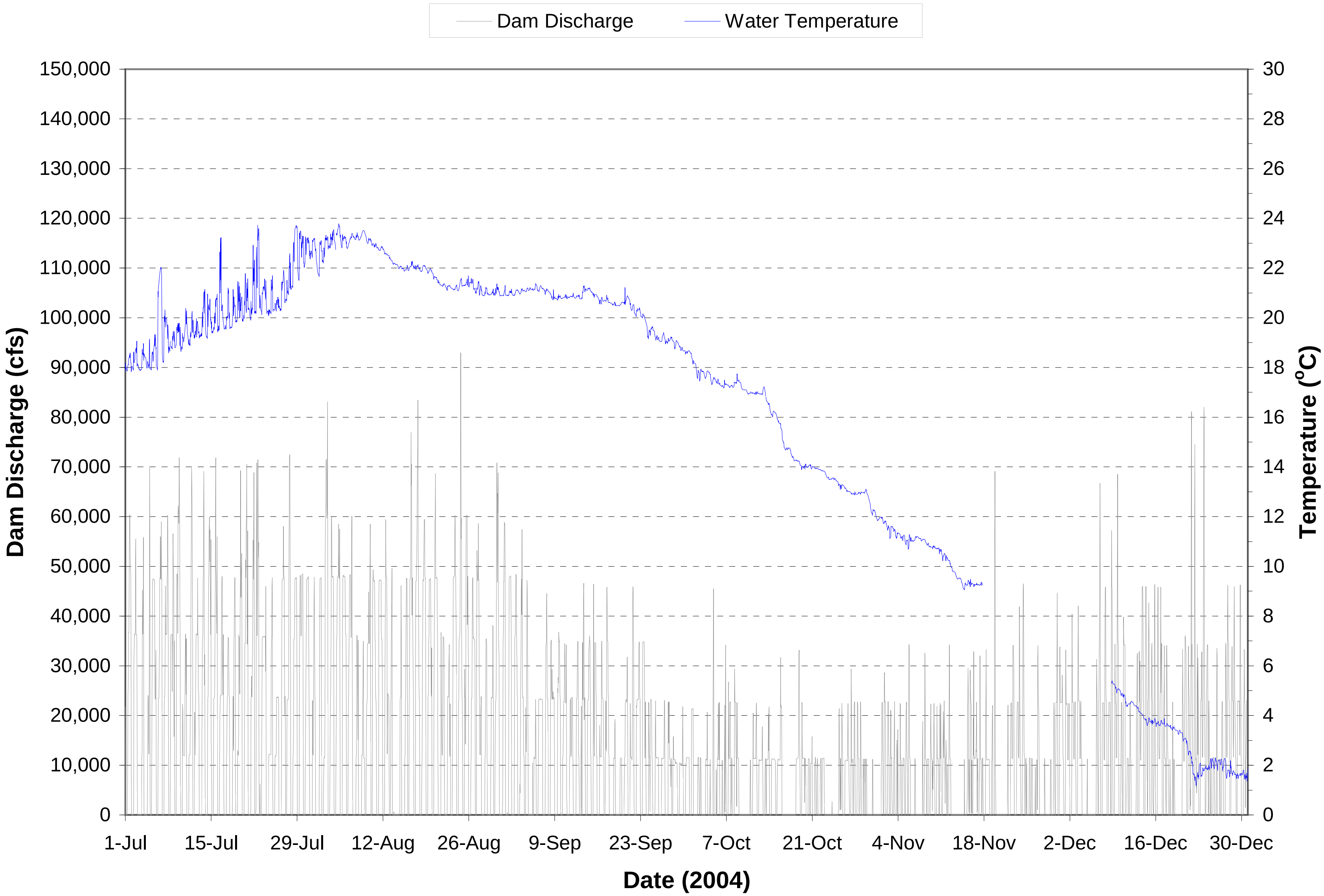


Plate 227. Hourly discharge and water temperature monitored at the Big Bend powerplant on water discharged through the dam during the period July through December 2004.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

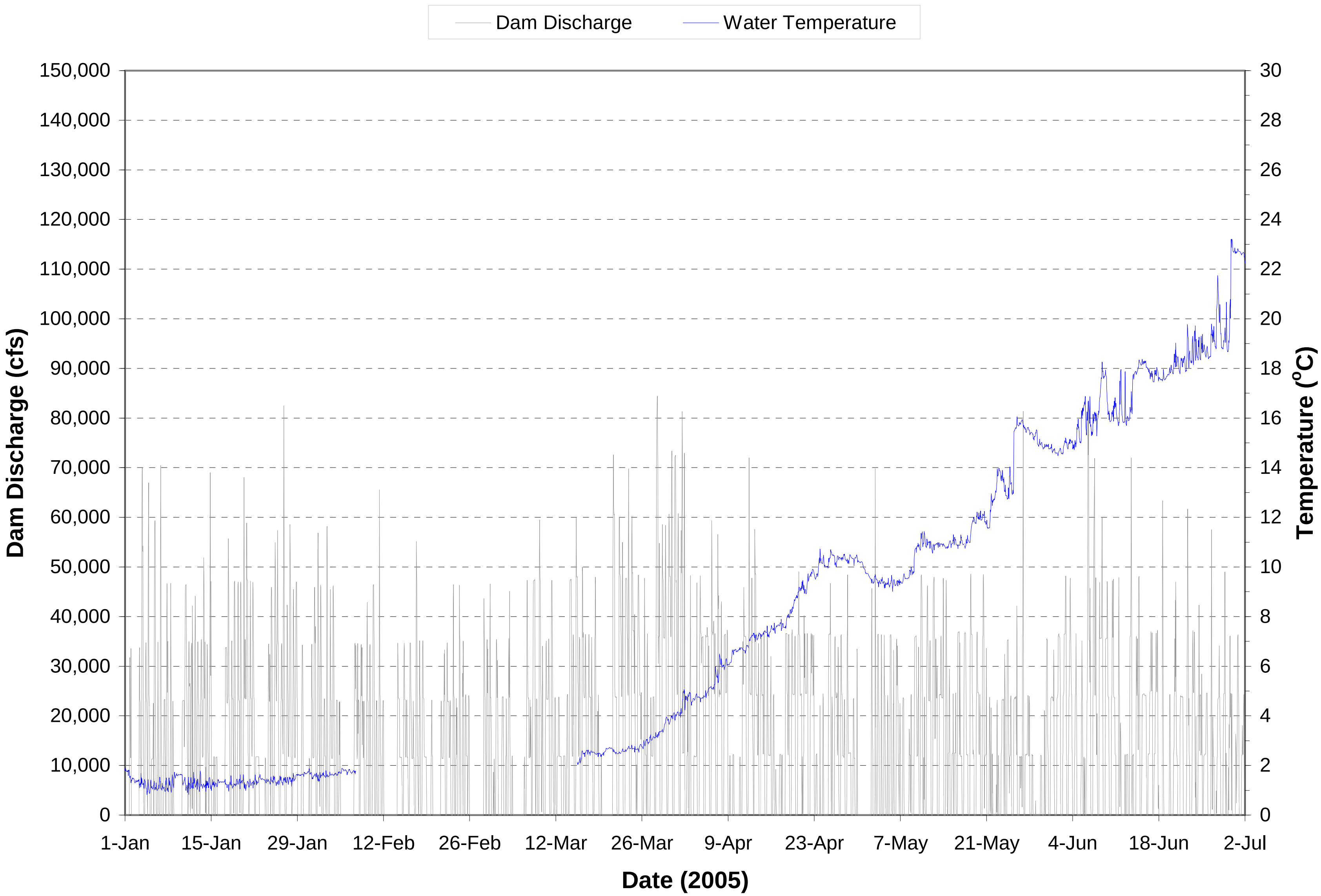


Plate 228. Hourly discharge and water temperature monitored at the Big Bend powerplant on water discharged through the dam during the period January through June 2005.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

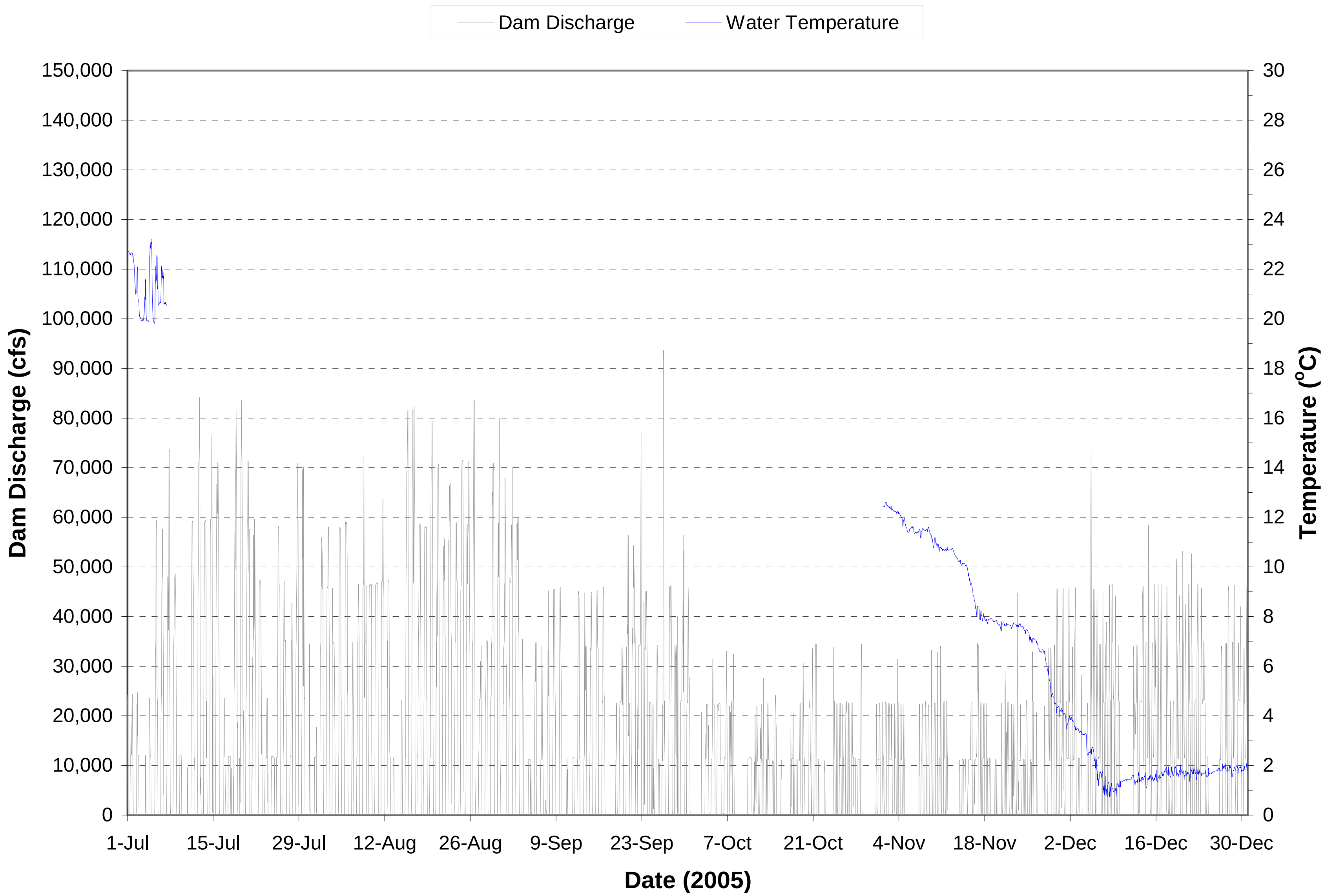


Plate 229. Hourly discharge and water temperature monitored at the Big Bend powerplant on water discharged through the dam during the period July through December 2005.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

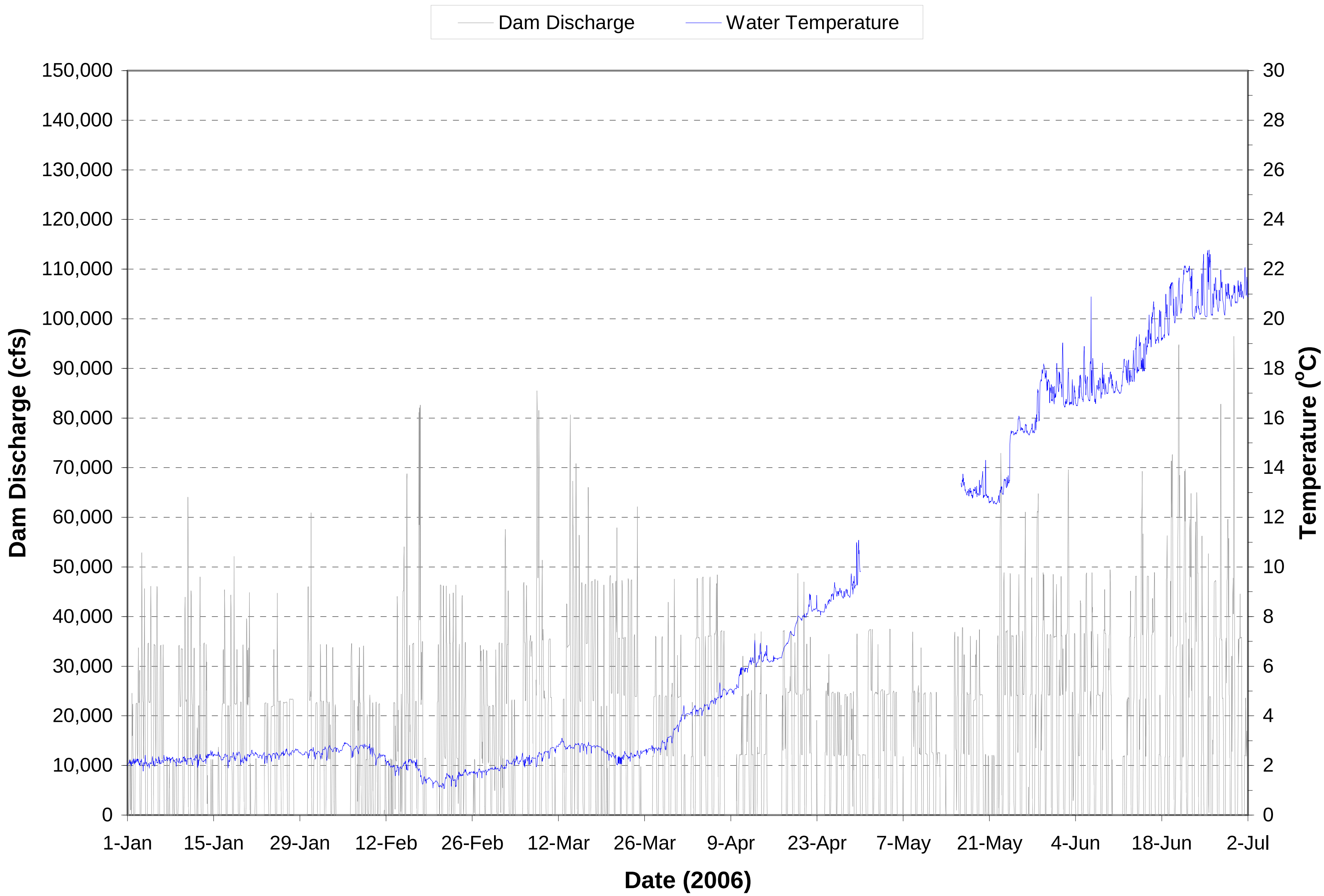


Plate 230. Hourly discharge and water temperature monitored at the Big Bend powerplant on water discharged through the dam during the period January through June 2006.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

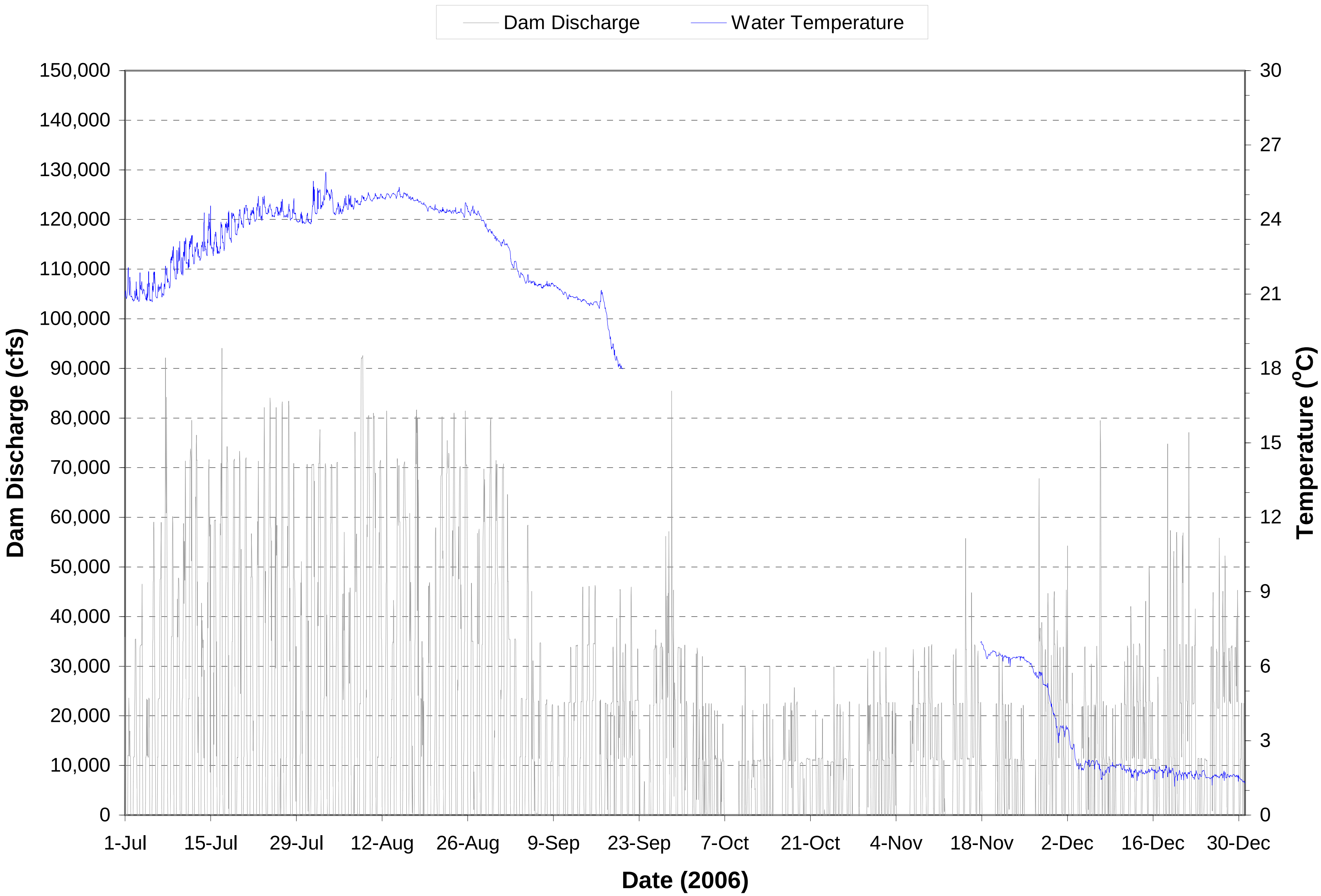


Plate 231. Hourly discharge and water temperature monitored at the Big Bend powerplant on water discharged through the dam during the period July through December 2006.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

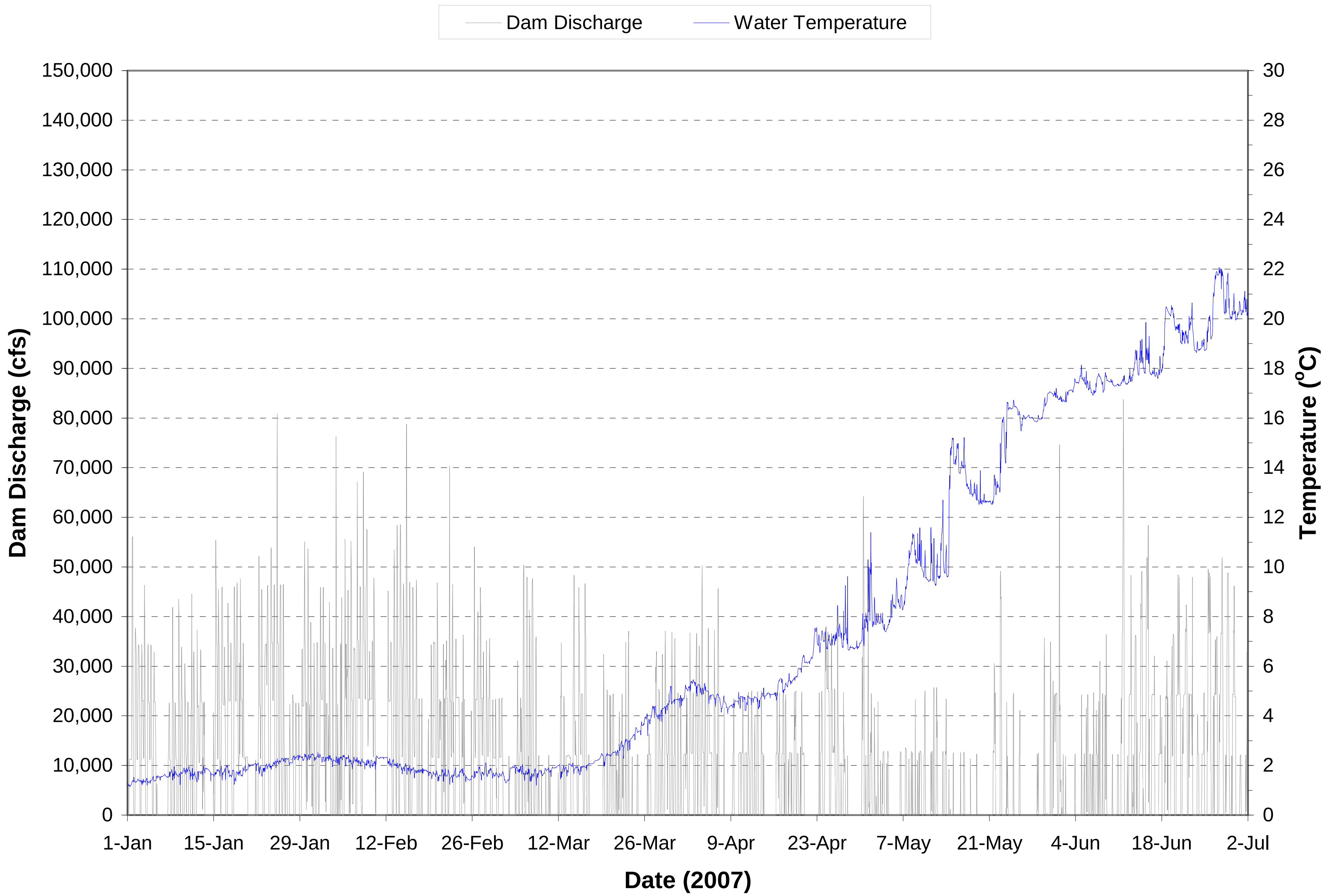


Plate 232. Hourly discharge and water temperature monitored at the Big Bend powerplant on water discharged through the dam during the period January through June 2007.

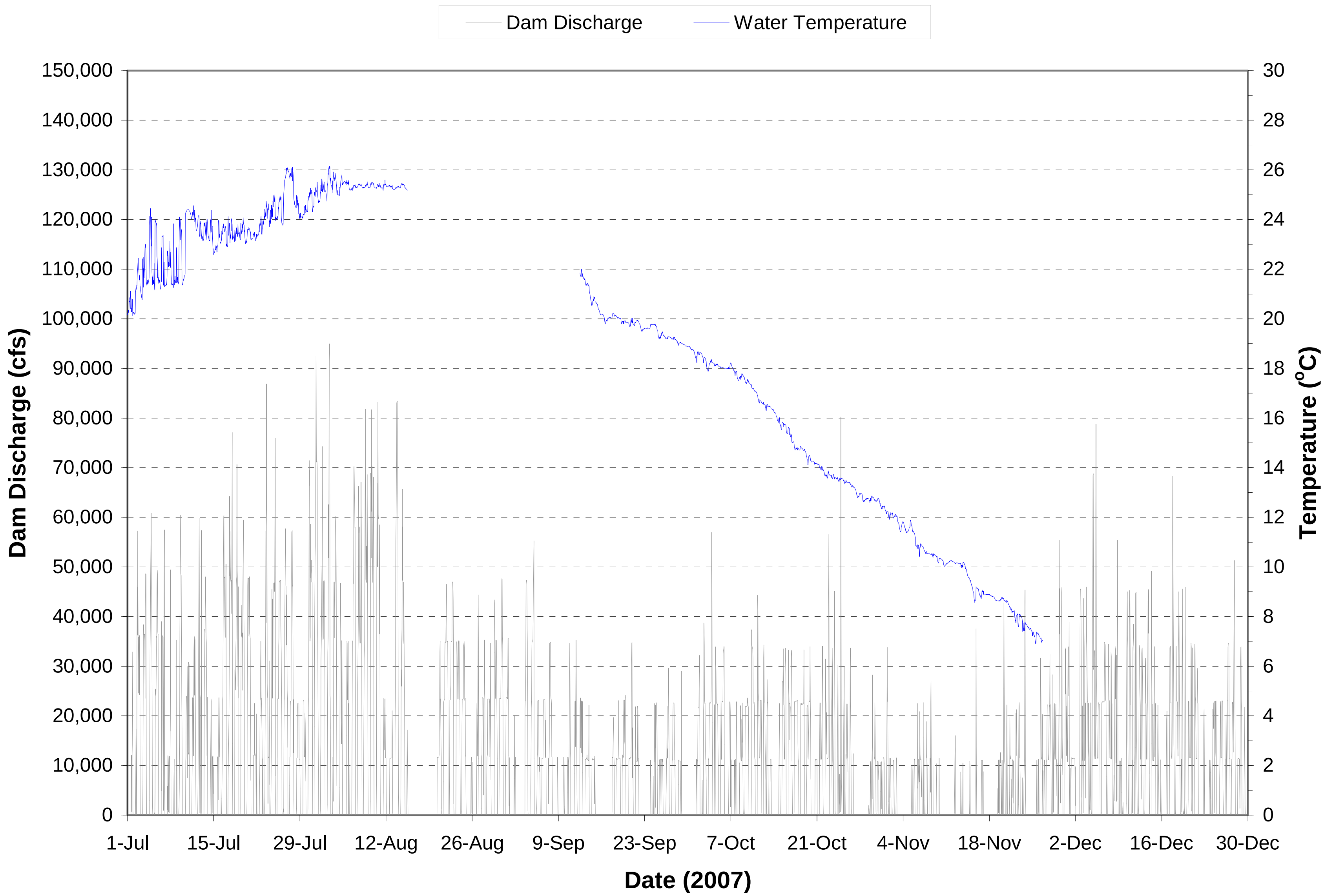


Plate 233. Hourly discharge and water temperature monitored at the Big Bend powerplant on water discharged through the dam during the period July through December 2007.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

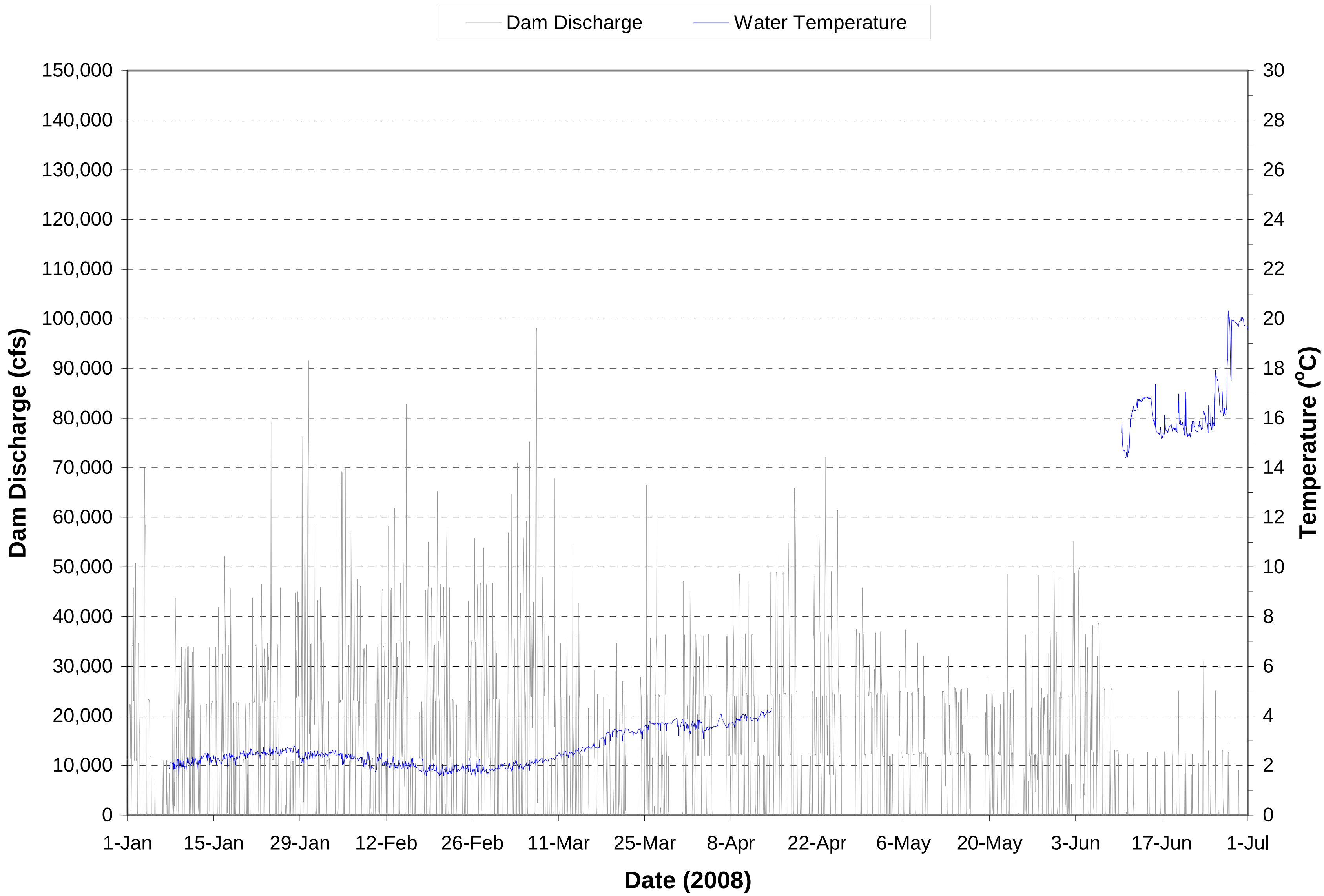


Plate 234. Hourly discharge and water temperature monitored at the Big Bend powerplant on water discharged through the dam during the period January through June 2008.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

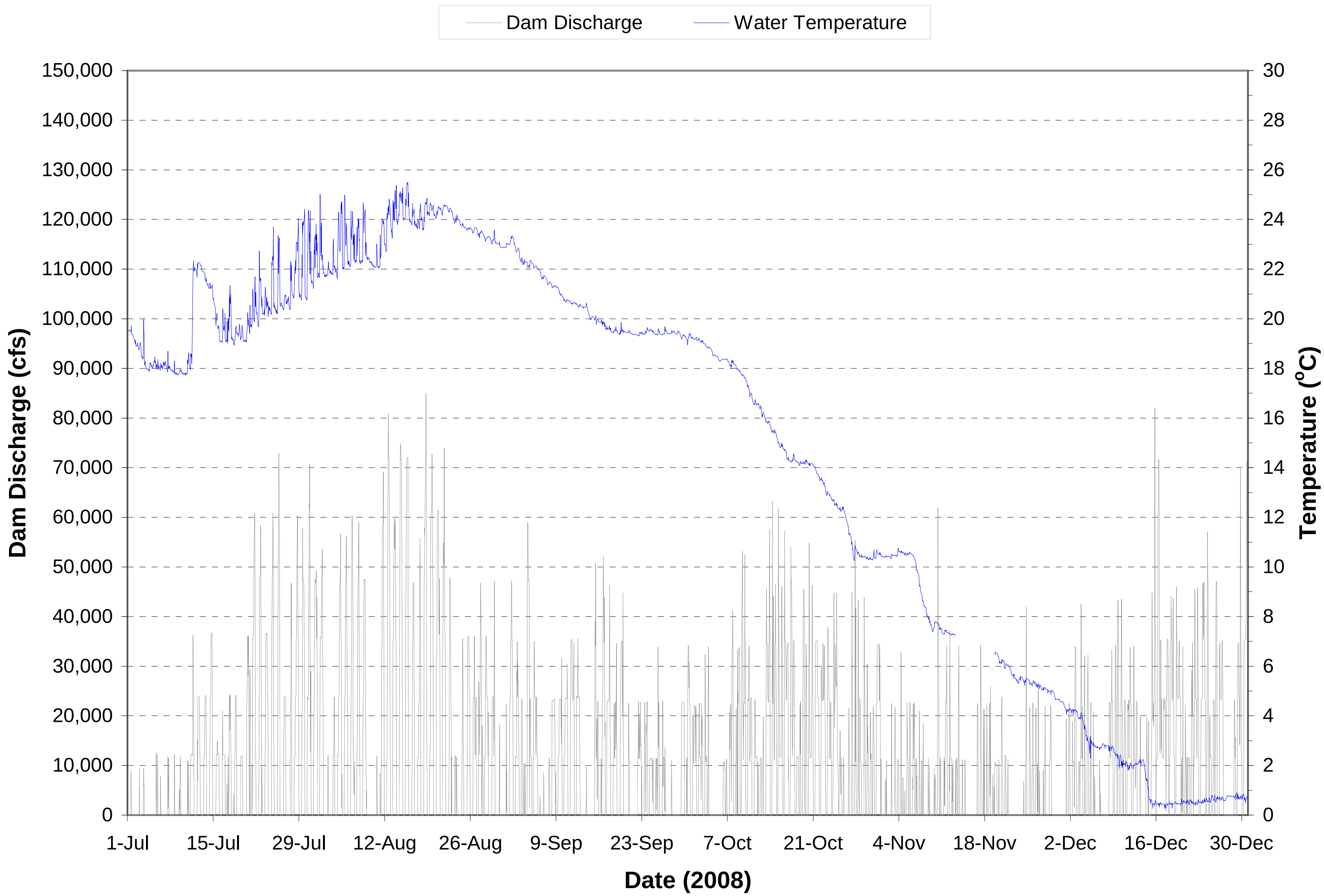


Plate 235. Hourly discharge and water temperature monitored at the Big Bend powerplant on water discharged through the dam during the period July through December 2008.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

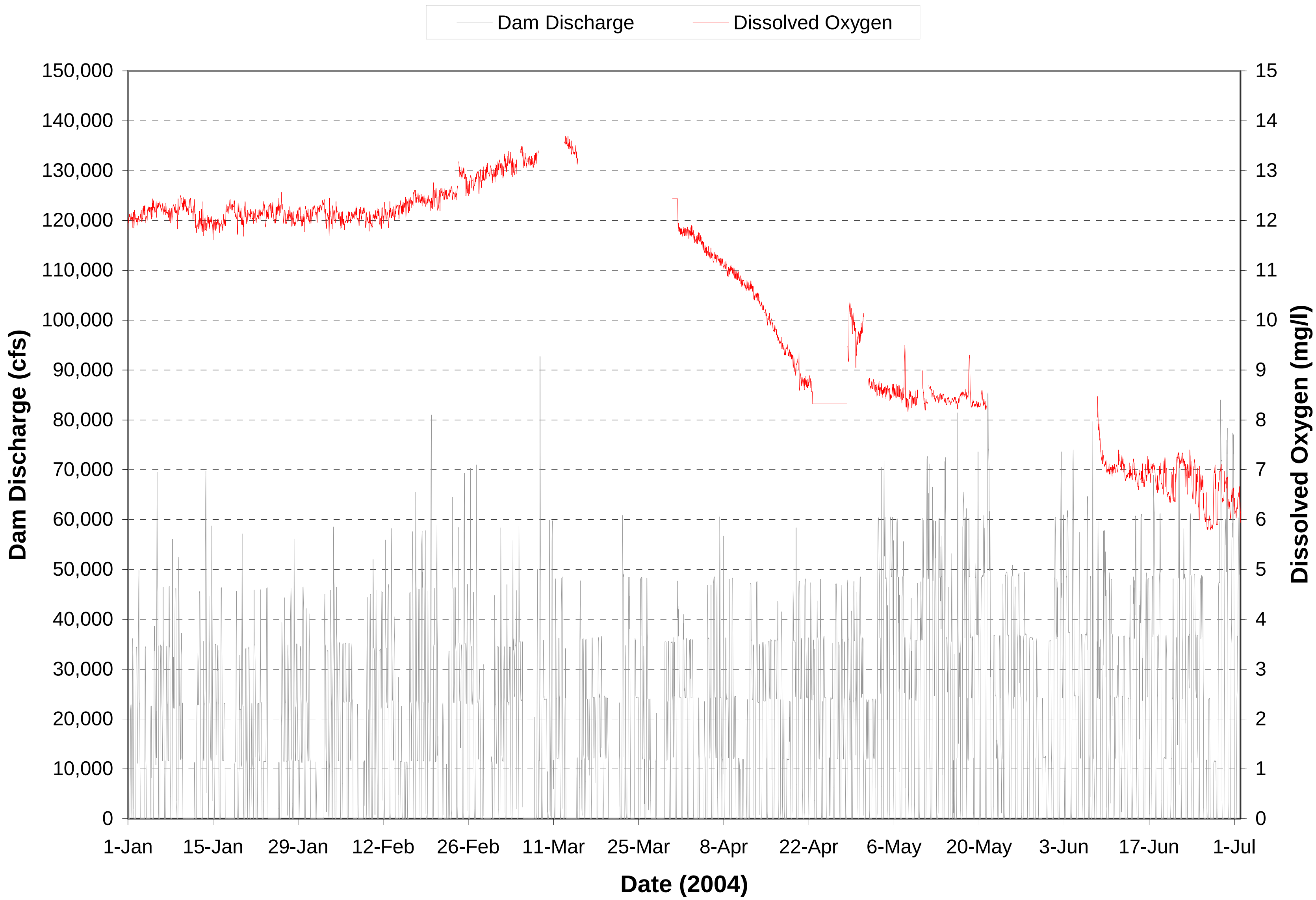


Plate 236. Hourly discharge and dissolved oxygen concentrations monitored at the Big Bend powerplant on water discharged through the dam during the period January through June 2004.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

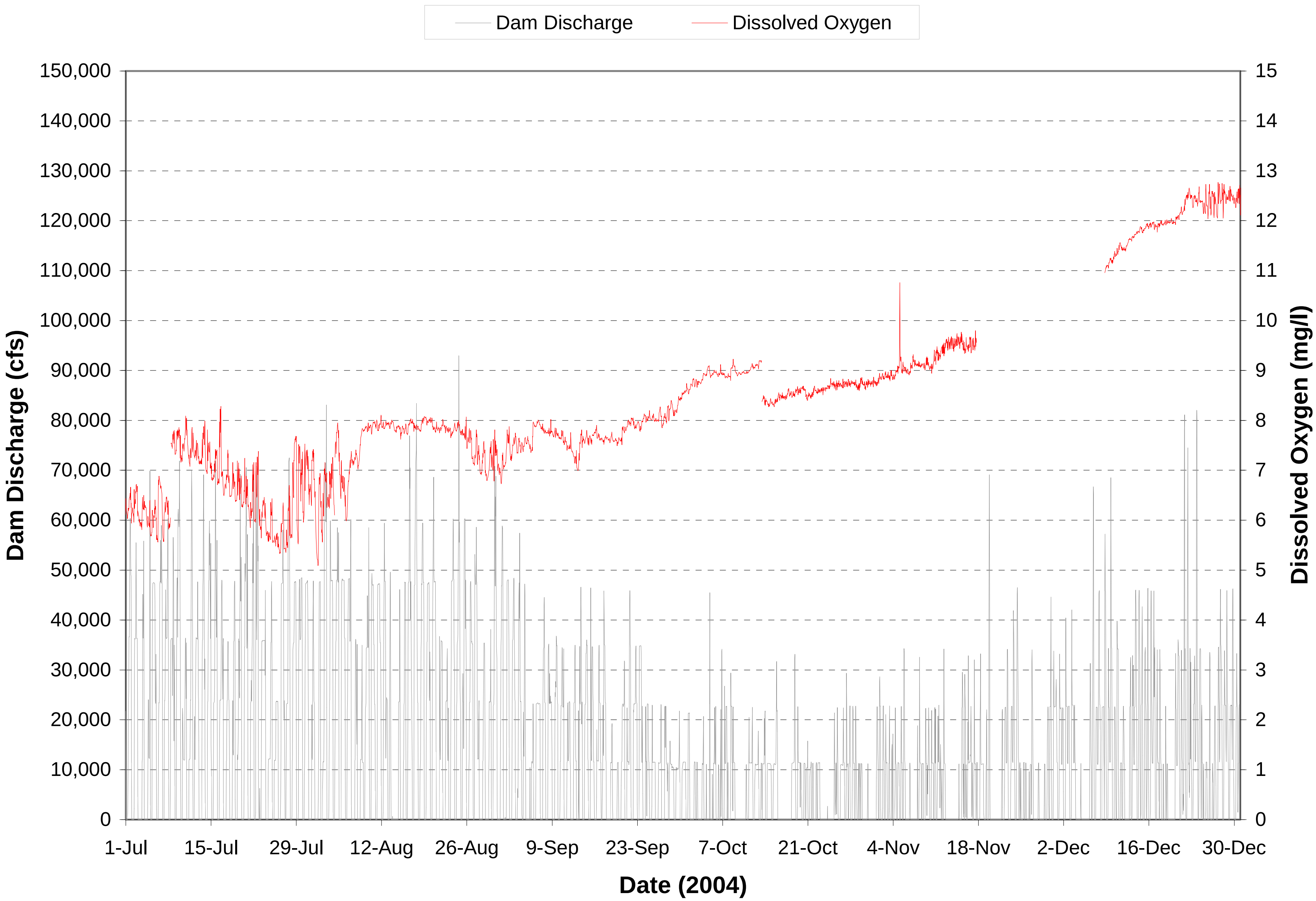


Plate 237. Hourly discharge and dissolved oxygen concentrations monitored at the Big Bend powerplant on water discharged through the dam during the period July through December 2004.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

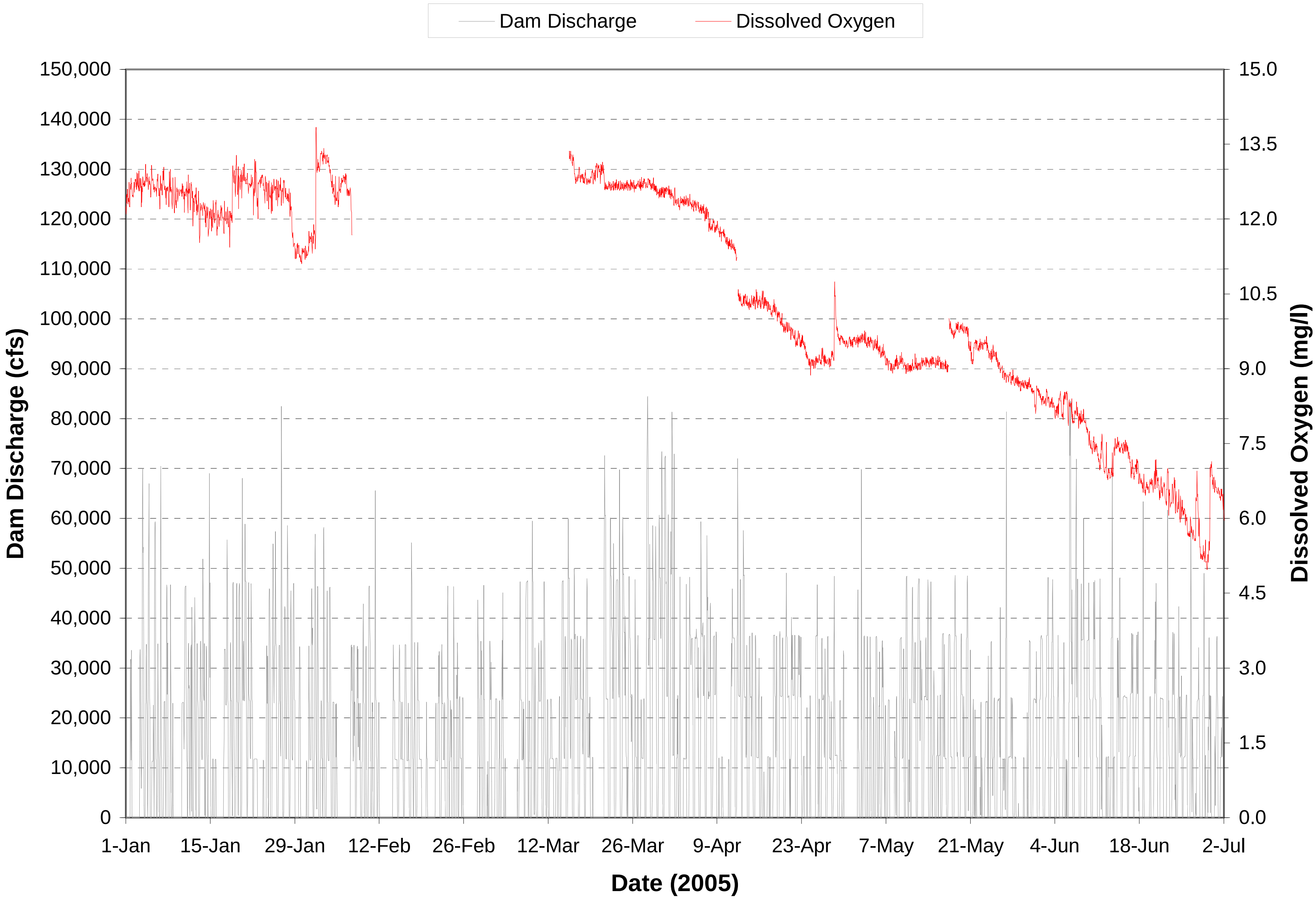


Plate 238. Hourly discharge and dissolved oxygen concentrations monitored at the Big Bend powerplant on water discharged through the dam during the period January through June 2005.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

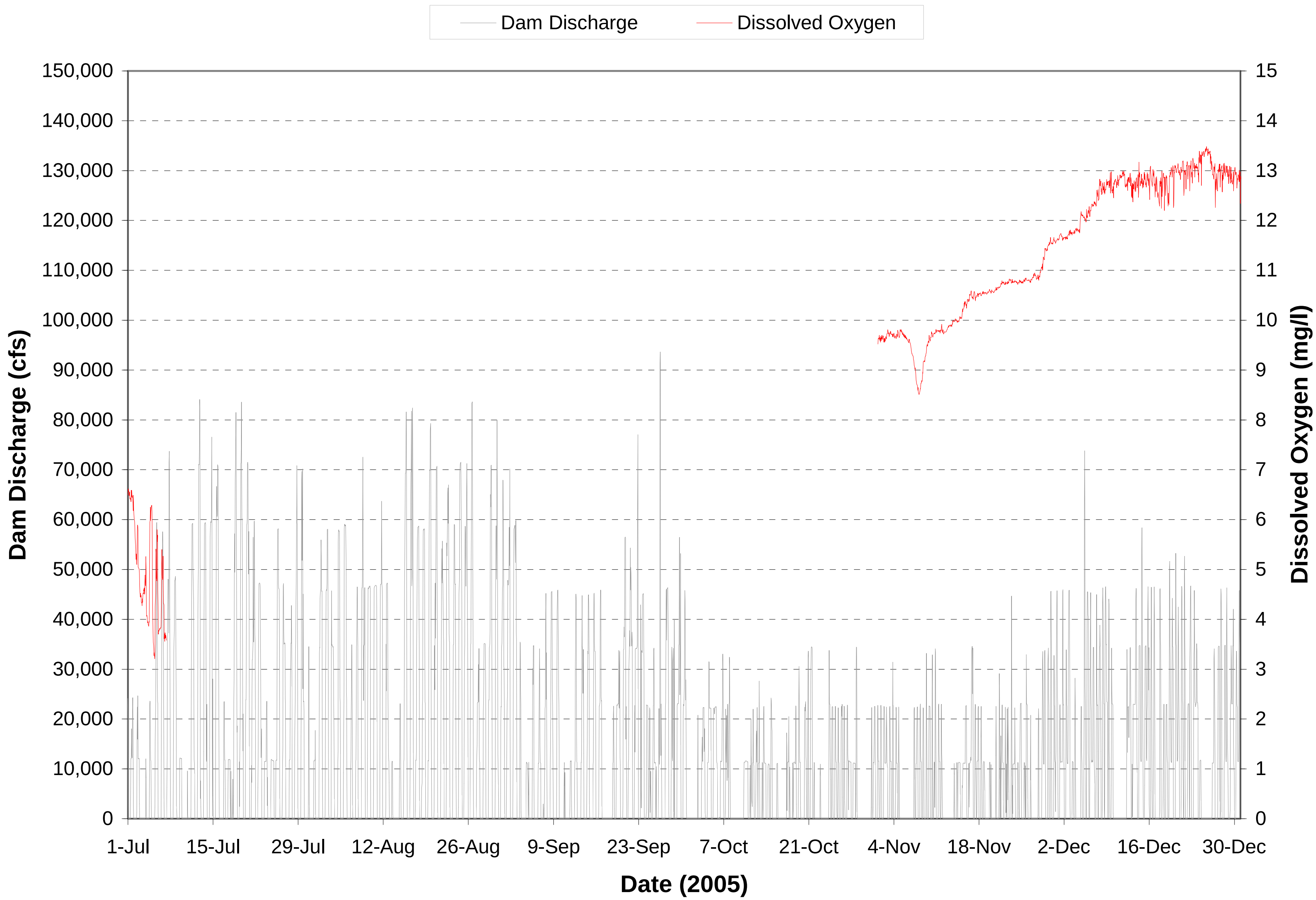


Plate 239. Hourly discharge and dissolved oxygen concentrations monitored at the Big Bend powerplant on water discharged through the dam during the period July through December 2005.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

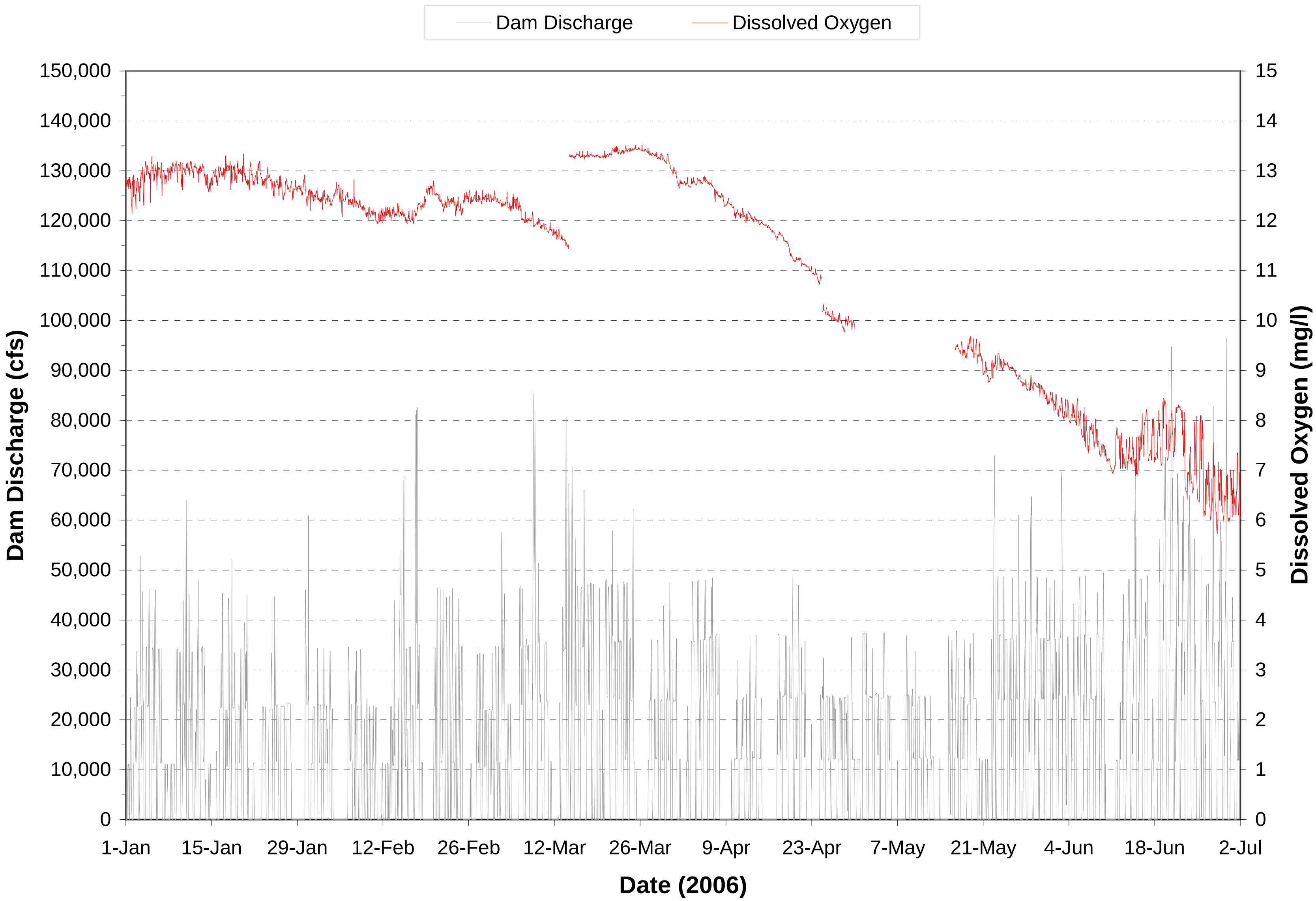


Plate 240. Hourly discharge and dissolved oxygen concentrations monitored at the Big Bend powerplant on water discharged through the dam during the period January through July 2006.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.

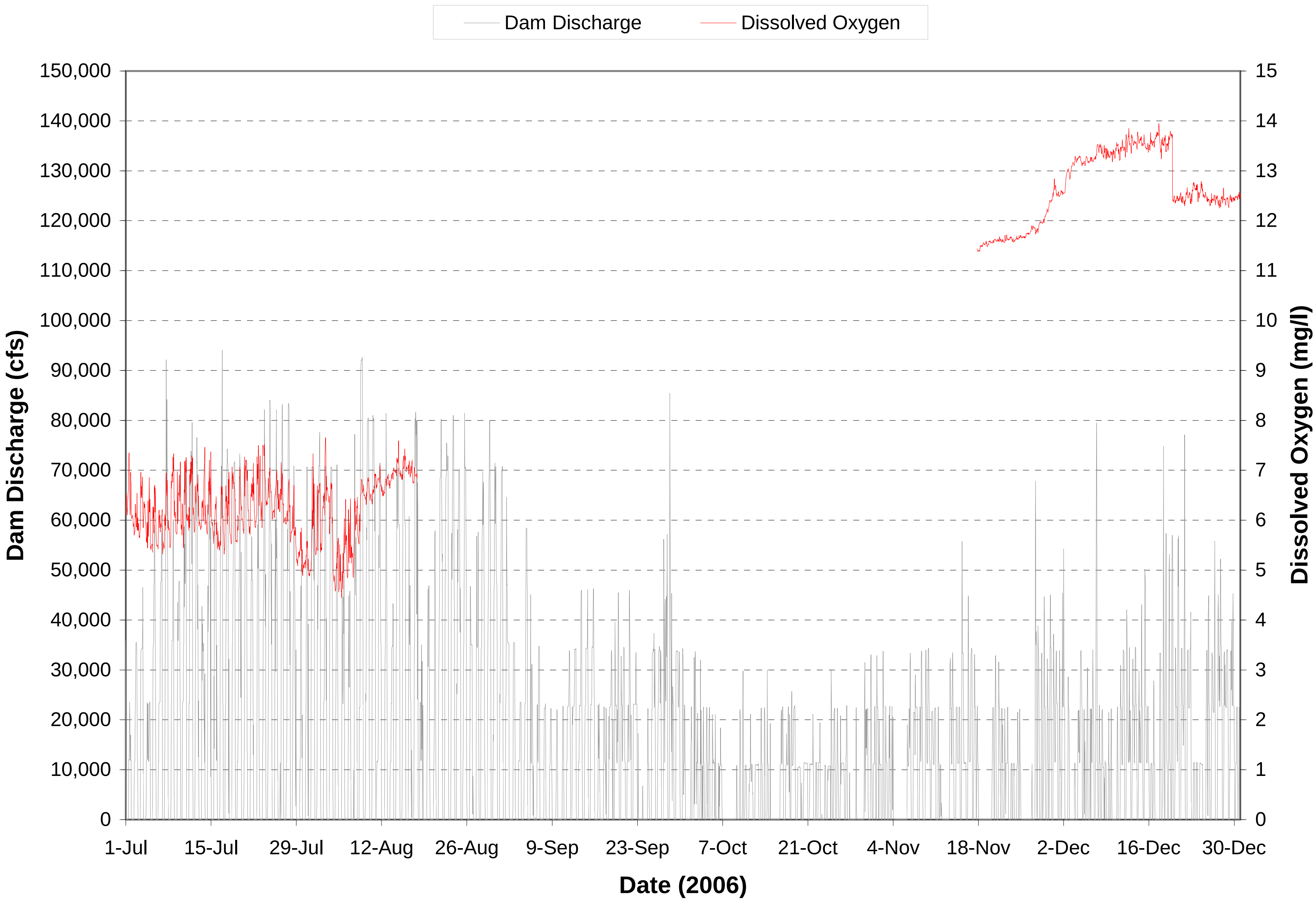


Plate 241. Hourly discharge and dissolved oxygen concentrations monitored at the Big Bend powerplant on water discharged through the dam during the period July through December 2006.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.

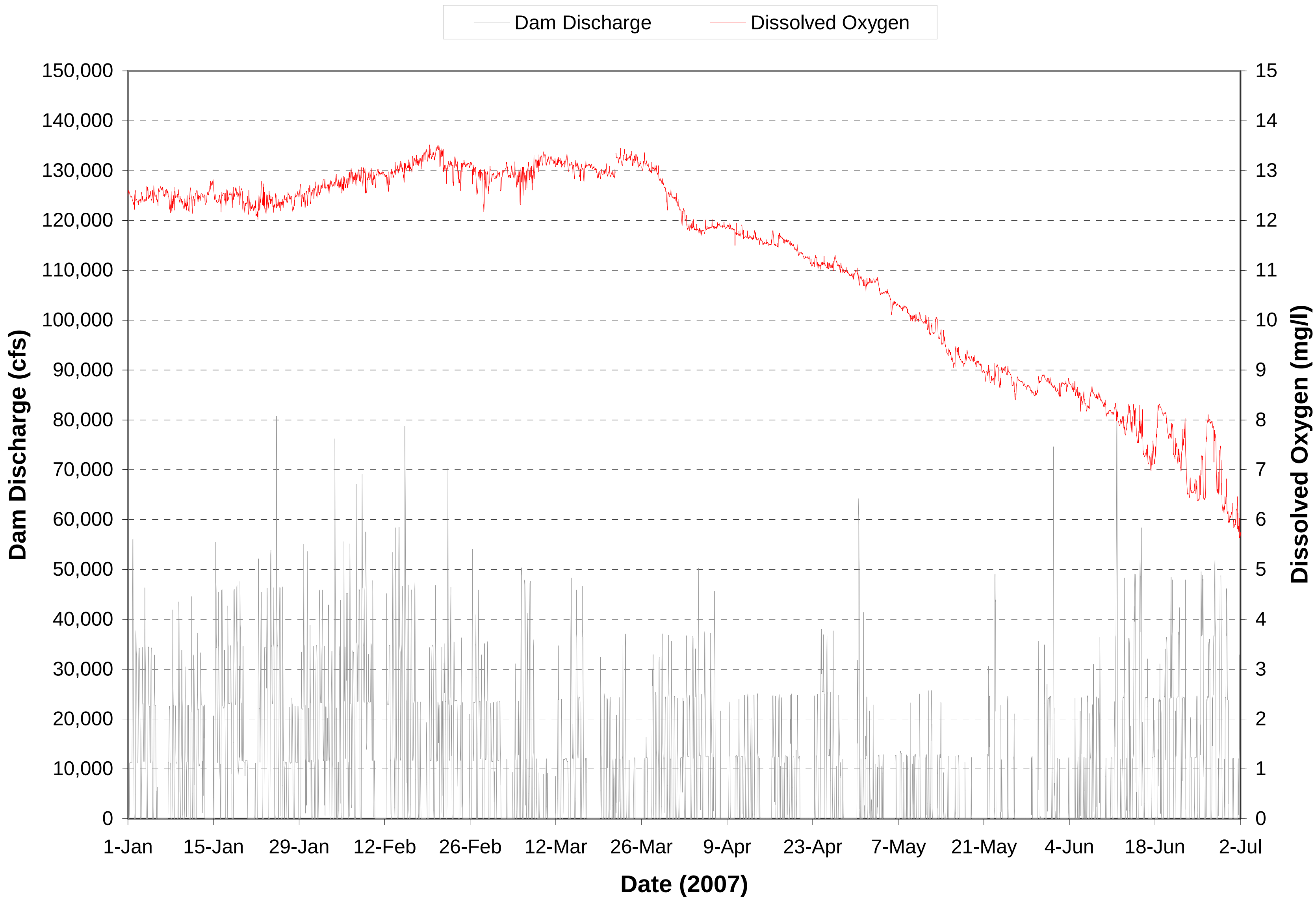


Plate 242. Hourly discharge and dissolved oxygen concentrations monitored at the Big Bend powerplant on water discharged through the dam during the period January through July 2007.

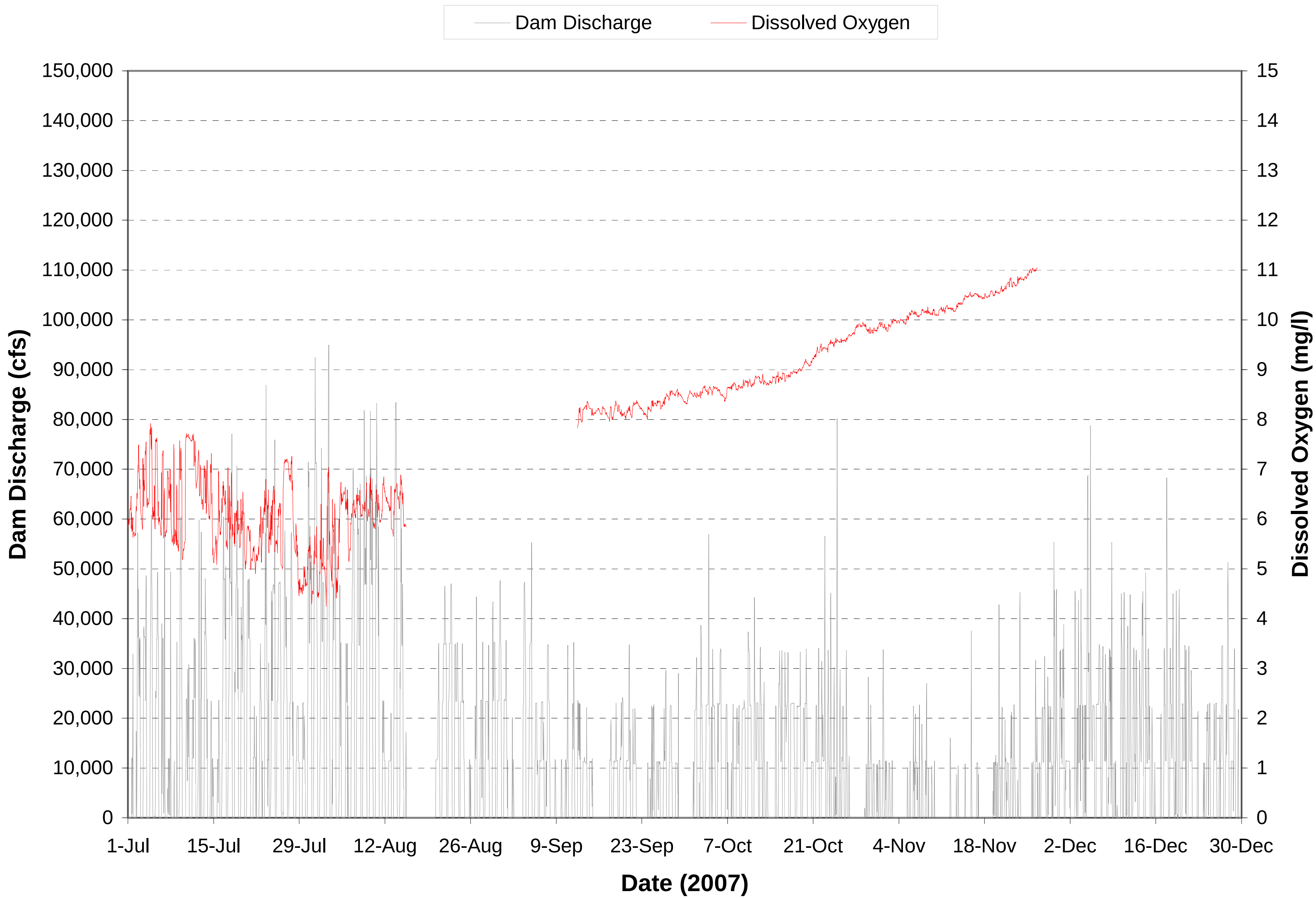


Plate 243. Hourly discharge and dissolved oxygen concentrations monitored at the Big Bend powerplant on water discharged through the dam during the period July through December 2007.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.

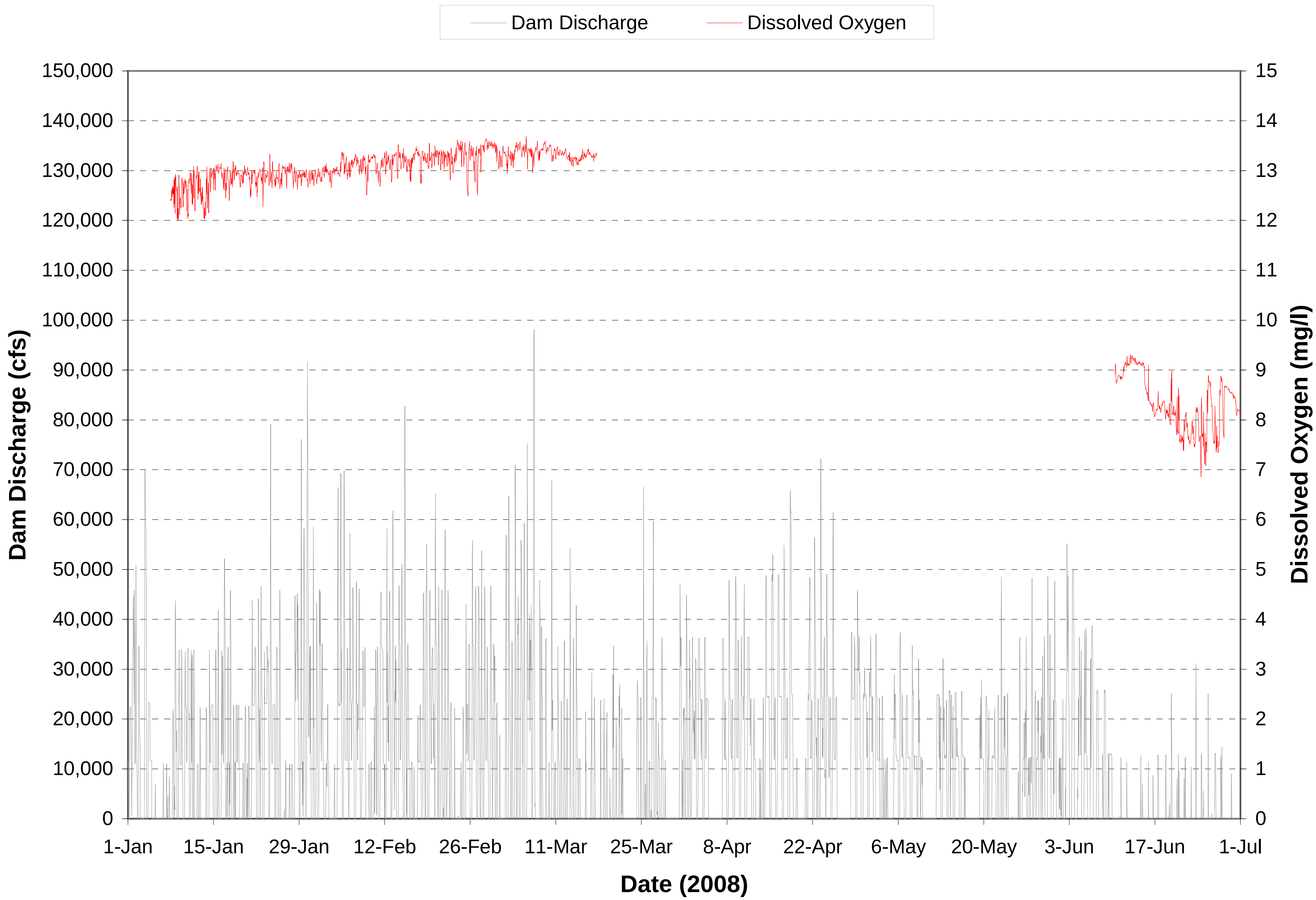


Plate 244. Hourly discharge and dissolved oxygen concentrations monitored at the Big Bend powerplant on water discharged through the dam during the period January through July 2008.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.

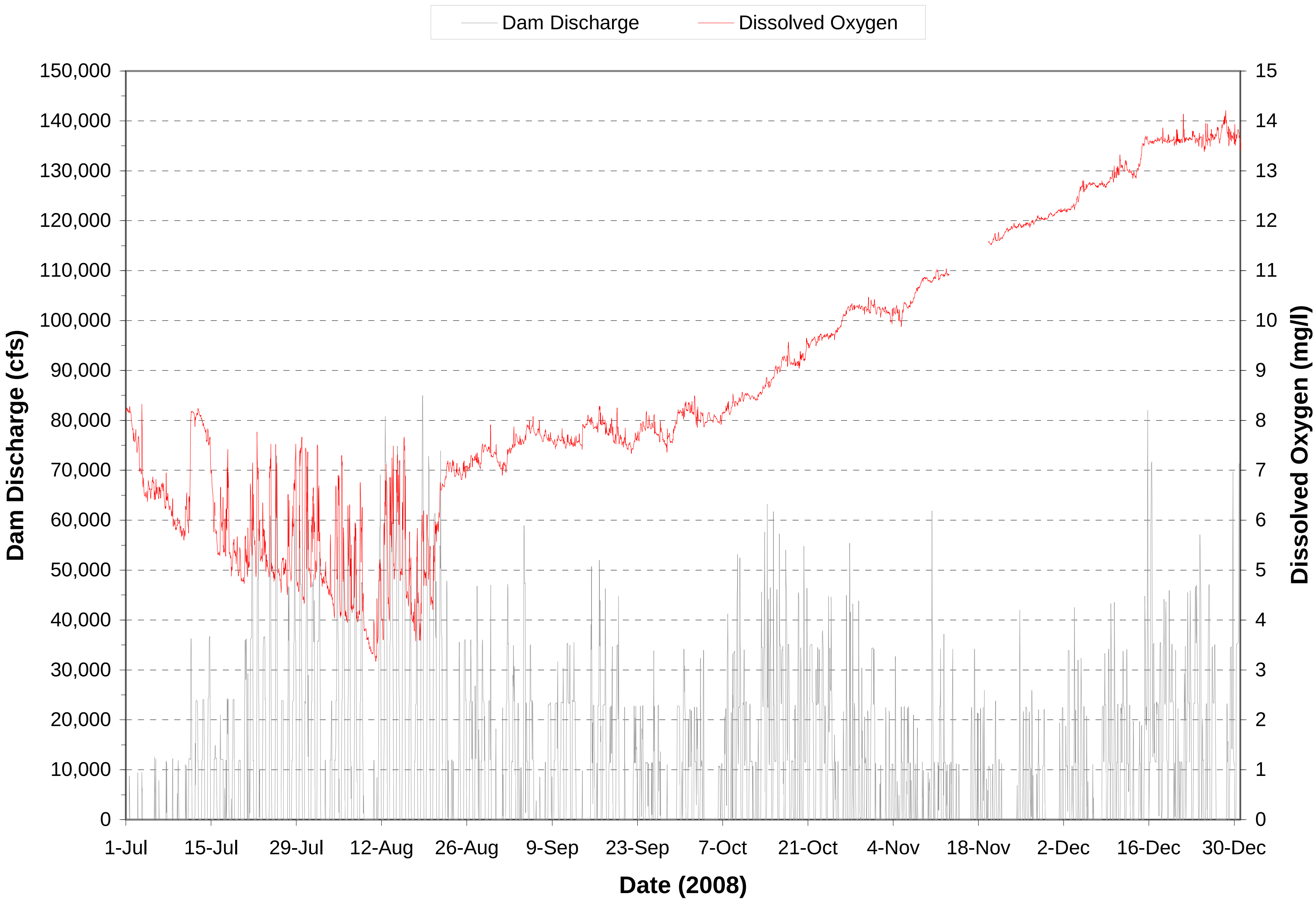


Plate 245. Hourly discharge and dissolved oxygen concentrations monitored at the Big Bend powerplant on water discharged through the dam during the period July through December 2008.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.

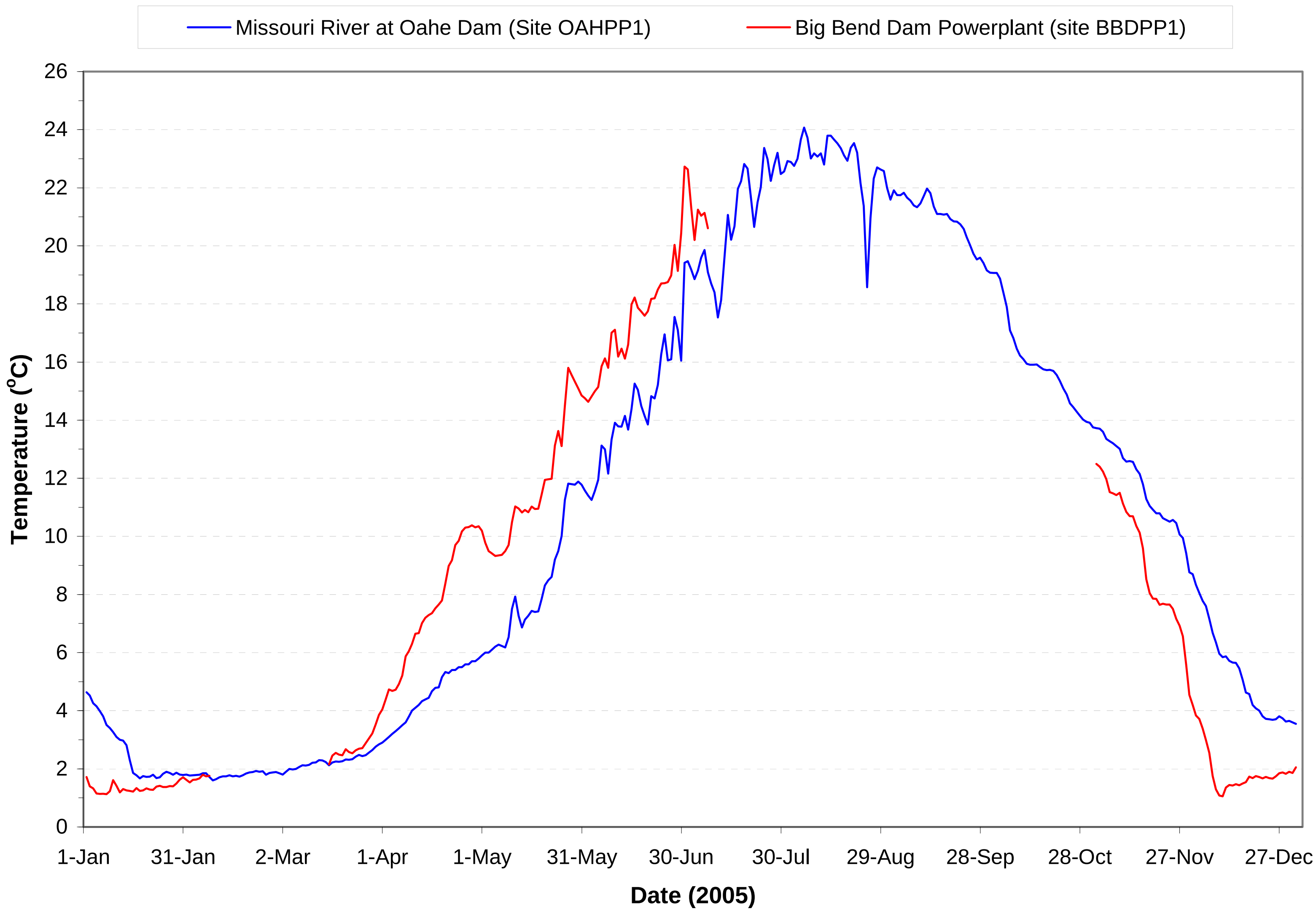


Plate 246. Mean daily water temperatures monitored at the Big Bend Powerplant (i.e., site BBDPP1) and the Missouri River at Oahe Dam (i.e., site OAHPP1) during 2005.
(Note: Gaps in temperature plots are periods when monitoring equipment was not operational.)

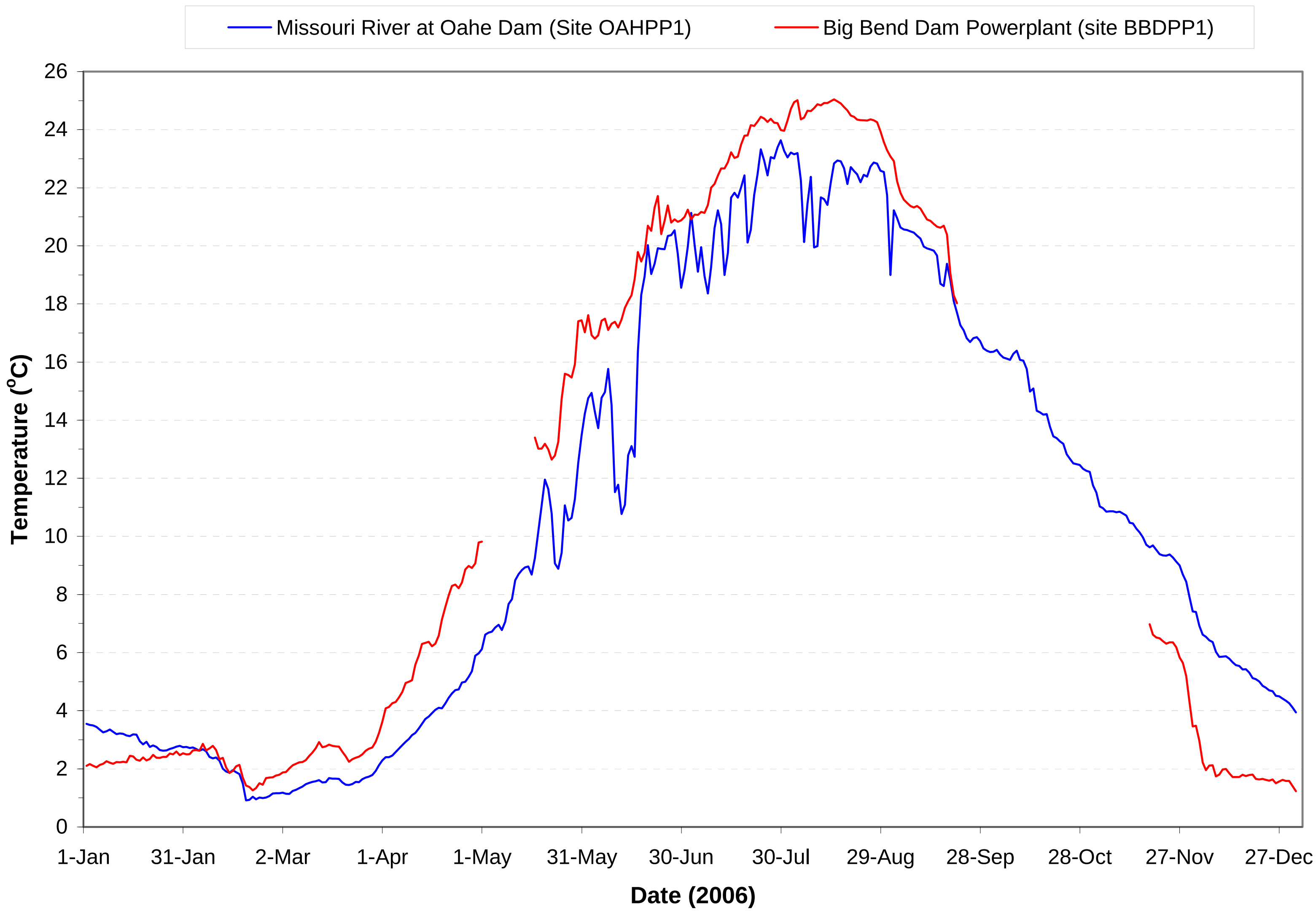


Plate 247. Mean daily water temperatures monitored at the Big Bend Powerplant (i.e., site BBDPP1) and the Missouri River at Oahe Dam (i.e., site OAHPP1) during 2006.
Note: Gaps in temperature plots are periods when monitoring equipment was not operational.)

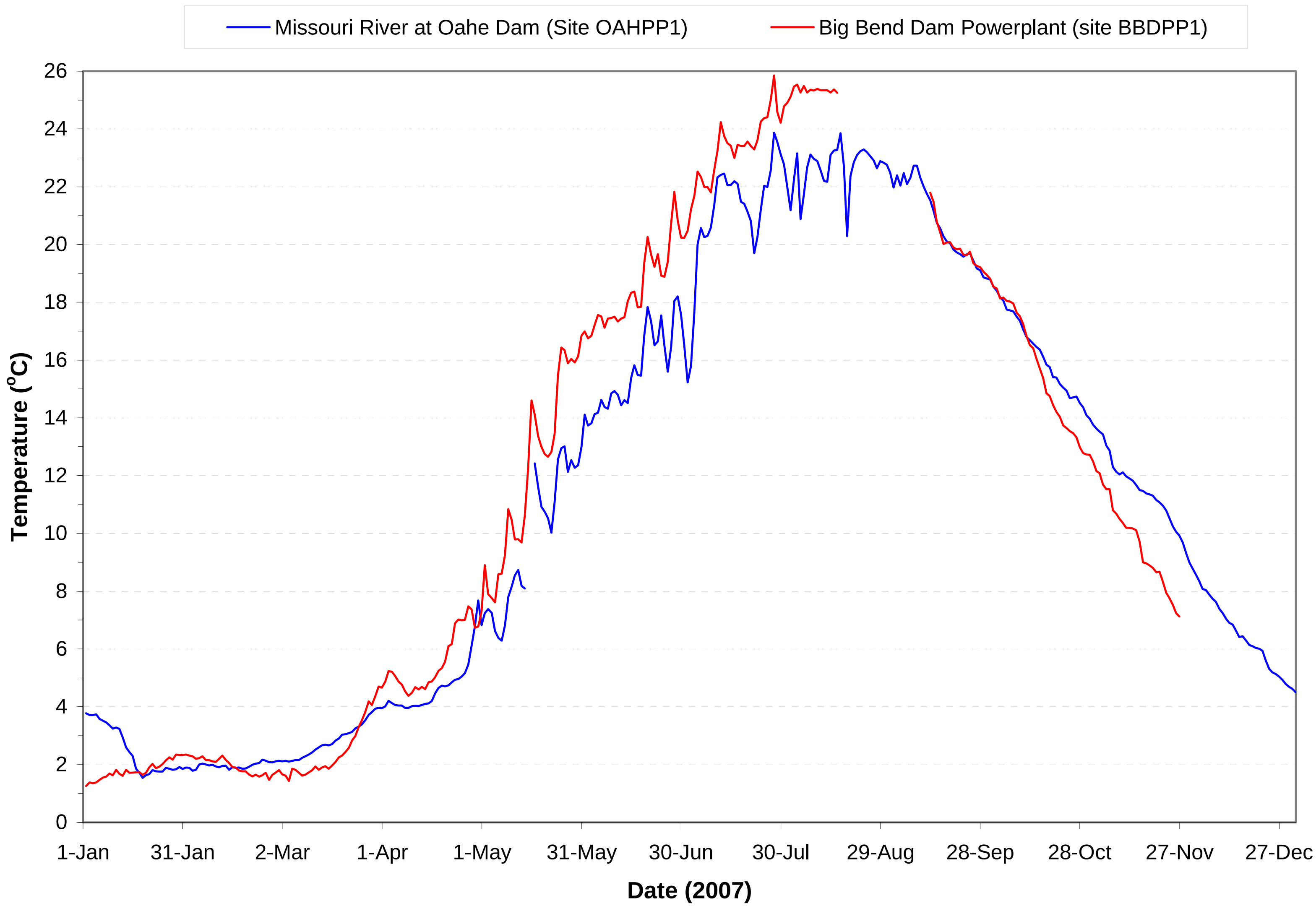


Plate 248. Mean daily water temperatures monitored at the Big Bend Powerplant (i.e., site BBDPP1) and the Missouri River at Oahe Dam (i.e., site OAHPP1) during 2007.
Note: Gaps in temperature plots are periods when monitoring equipment was not operational.)

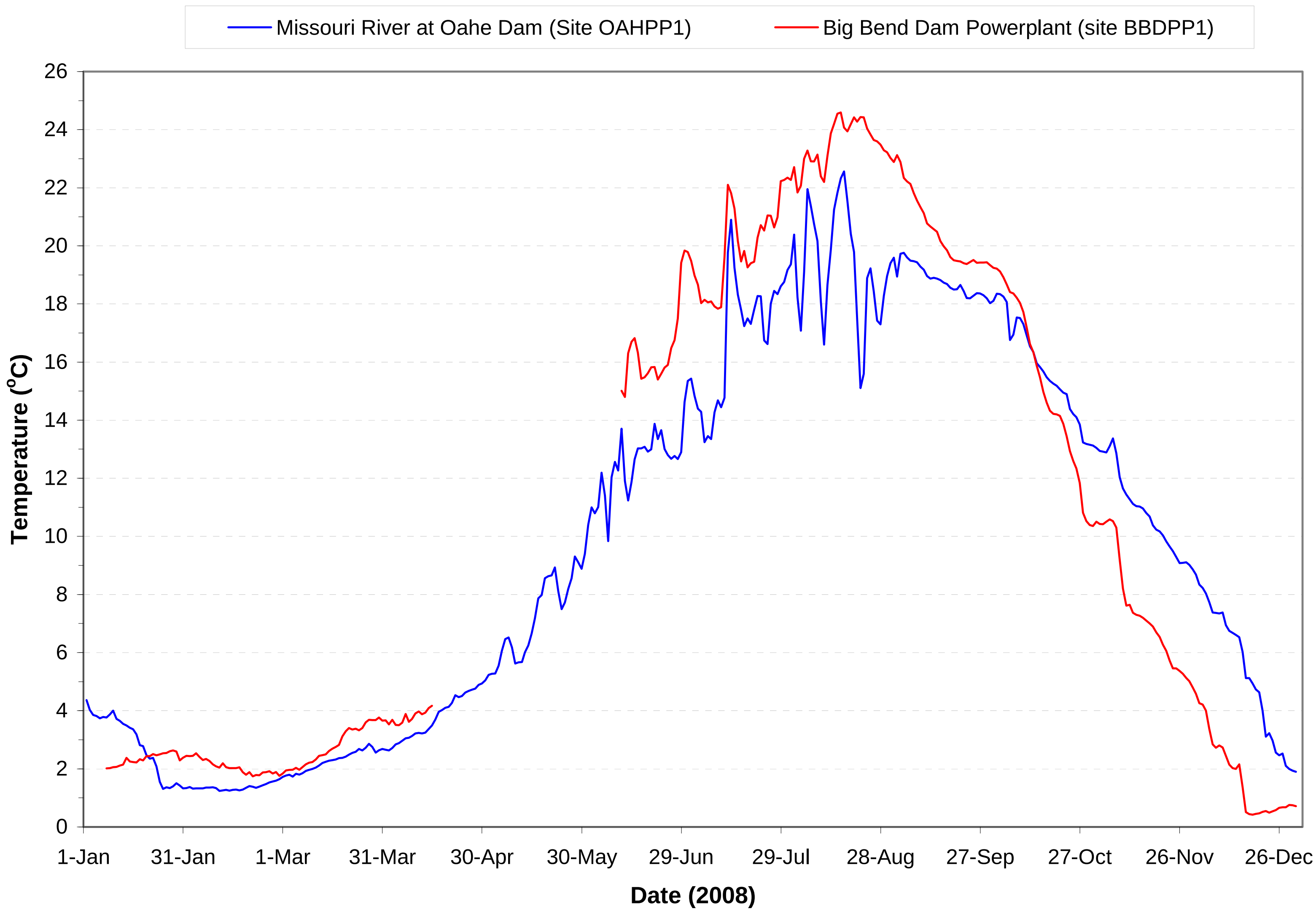


Plate 249. Mean daily water temperatures monitored at the Big Bend Powerplant (i.e., site BBDPP1) and the Missouri River at Oahe Dam (i.e., site OAHPP1) during 2008.
Note: Gaps in temperature plots are periods when monitoring equipment was not operational.)

Plate 250. Summary of monthly (May through September) water quality conditions monitored in Fort Randall Reservoir near Fort Randall Dam (Site FTRLK0880A) during the 5-year period 2004 through 2008.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	25	1354.5	1354.4	1346.7	1361.8	-----	-----	-----
Water Temperature (C)	0.1	815	18.8	20.4	6 3	28.1	27[1,5]	3	<1%
Dissolved Oxygen (mg/l)	0.1	812	8.2	8.0	1.8	11.5	5[1,6]	30	4%
Dissolved Oxygen (% Sat.)	0.1	812	91.0	93.6	20.7	107.3	----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	704	8.3	8.0	4.8	11.5	5[3,6]	1	<1%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	108	7.5	7.8	1.8	11.2	5[1,6]	29	27%
Specific Conductance (umho/cm)	1	815	697	716	571	789	-----	-----	-----
pH (S.U.)	0.1	746	8 3	8.4	7.4	9.0	6.5[1,2,6], 9.0[1,2,5], 9.5[4,5]	0	0%
Turbidity (NTUs)	1	809	4	3	n.d.	32	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	815	350	350	253	433	-----	-----	-----
Secchi Depth (in.)	1	25	106	101	51	229	-----	-----	-----
Alkalinity, Total (mg/l)	7	48	165	161	140	202	-----	-----	-----
Ammonia, Total (mg/l)	0.02	48	-----	0.05	n.d.	0.27	3.9 [1,5,8], 0.84 [1,7,8]	0	0%
Carbon, Total Organic (mg/l)	0.05	46	3.0	3.1	1.7	3.6	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	32	10	10	n.d.	21	-----	-----	-----
Chloride (mg/l)	1	32	11	11	9	12	175[1,5], 100[1,7], 438[2,5], 250[2,7]	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	774	-----	1	n.d.	9	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	24	-----	1	n.d.	9	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	34	477	470	440	550	1,750[2,5], 1,000[2,7], 3,500[4,5], 2,000[4,7]	0	0%
Iron, Total (ug/l)	40	20	85	90	n.d.	194	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	48	0.4	0.3	n.d.	0.8	-----	-----	-----
Manganese, Total (ug/l)	2	20	34	18	n.d.	141	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	48	-----	n.d.	n.d.	0.24	10[2,5]	0	0%
Phosphorus, Dissolved (mg/l)	0.02	29	-----	n.d.	n.d.	0.08	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	48	0.04	0.03	n.d.	0.25	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	46	-----	n.d.	n.d.	0.06	-----	-----	-----
Sulfate (mg/l)	1	34	211	211	176	230	875[2,5], 500[2,7]	0	0%
Suspended Solids, Total (mg/l)	4	48	-----	n.d.	n.d.	8	158[1,5], 90[1,7]	0	0%
Microcystin, Total (ug/l)	0.2	19	-----	n.d.	n.d.	1.8	-----	-----	-----

n.d. = Not detected.

[A] Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

[B] Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

[C] Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

[D] Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for the protection of warmwater permanent fish life propagation waters.
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of immersion and limited contact recreation waters (applies only to epilimnion and metalimnion if water body stratified).
- (4) Criteria for the protection of commerce and industry waters.
- (5) Daily maximum criterion (monitoring results directly comparable to criterion).
- (6) Daily minimum criterion (monitoring results directly comparable to criterion).
- (7) 30-day average criterion (monitoring results not directly comparable to criterion).
- (8) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

[E] A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5 C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1 C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5 C occurs over a 1-meter depth increment.

Plate 251. Summary of monthly (June through September) water quality conditions monitored in Fort Randall Reservoir near Pease Creek (site FTRLK0892DW) during the 3-year period 2006 through 2008.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	**No. of Obs.**	**Mean[C]**	**Median**	**Min.**	**Max.**	**State WQS Criteria[D]**	**No. of WQS Exceedences**	**Percent WQS Exceedence**
Pool Elevation (ft-msl)	0.1	12	1354.0	1354.4	1346.7	1362.0	-----	-----	-----
Water Temperature (C)	0.1	346	21.2	21.4	9.7	26.2	27(1,5)	0	0%
Dissolved Oxygen (mg/l)	0.1	345	7.7	7.9	1.5	9.8	5(1,6)	19	6%
Dissolved Oxygen (% Sat.)	0.1	345	89.8	93.3	18.0	104.5	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	301	7.9	7.9	5.2	9.8	5(3,6)	0	0%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	44	6.2	6.9	1.5	9.8	5(1,6)	19	43%
Specific Conductance (umho/cm)	1	346	728	730	698	740	-----	-----	-----
pH (S.U.)	0.1	317	8.4	8.4	7.7	8.8	6.5(1,2,6), 9.0(1,2,5), 9.5(4,5)	0	0%
Turbidity (NTUs)	1	345	3	2	n.d.	23	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	346	329	320	252	427	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	341	2	1	n.d.	5	-----	-----	-----
Secchi Depth (in)	1	11	107	96	56	194	-----	-----	-----

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. The mean is not reported if 20% or more of the observations were nondetects. The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for the protection of warmwater permanent fish life propagation waters.
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of immersion and limited contact recreation waters (applies only to epilimnion and metalimnion if water body stratified).
- (4) Criteria for the protection of commerce and industry waters.
- (5) Daily maximum criterion (monitoring results directly comparable to criterion).
- (6) Daily minimum criterion (monitoring results directly comparable to criterion).

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5 C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1 C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0 5 C occurs over a 1-meter depth increment

Plate 252. **S**ummary of monthly (June through September) water quality conditions monitored in Fort Randall Reservoir near Platte Creek (Site FTRLK0911DW) during the 3-year period 2006 through 2008.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	12	1354.0	1354.4	1346.7	1361.9	-----	-----	-----
Water Temperature (C)	0.1	291	21.6	22.1	10.8	26.5	27(1,5)	0	0%
Dissolved Oxygen (mg/l)	0.1	291	7.7	7.9	0.9	9.7	5(1,6)	9	3%
Dissolved Oxygen (% Sat.)	0.1	291	90.2	92.9	10.4	106.3	----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	256	7.8	7.9	5.2	9.5	5(3,6)	0	0%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	35	6.4	6.6	0.9	9.7	5(1,6)	9	26%
Specific Conductance (umho/cm)	1	291	724	725	703	743	-----	-----	-----
pH (S.U.)	0.1	267	8.4	8.5	7.7	8.8	6.5(1,2,6), 9.0(1,2,5), 9.5(4,5)	0	0%
Turbidity (NTUs)	1	291	5	4	1	26	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	291	325	309	247	425	-----	-----	-----
Secchi Depth (in.)	1	12	80	74	48	148	-----	-----	-----
Alkalinity, Total (mg/l)	7	23	161	156	110	319	-----	-----	-----
Ammonia, Total (mg/l)	0.02	23	-----	0.03	n.d.	0.23	3.2(1,5,8), 0.63(1,7,8)	0	0%
Carbon, Total Organic (mg/l)	0.05	21	3.0	2.9	2.2	3.7	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	23	11	12	n.d.	19	-----	-----	-----
Chloride (mg/l)	1	23	11	11	9	12	175(1,5), 100(1,7), 438(2,5), 250(2,7)	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	282	3	2	n.d.	11	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	12	5	5	2	10	-----	-----	-----
Dissolved Solids, Total (mg/l)	4	23	478	480	448	510	1,750(2,5), 1,000(2,7), 3,500(4,5), 2,000(4,7)	0	0%
Iron, Total (ug/l)	40	19	113	100	40	240	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	23	0.4	0.3	n.d.	0.9	-----	-----	-----
Manganese, Total (ug/l)	2	19	45	32	10	160	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	23	-----	n.d.	n.d.	0.19	10(2,5)	0	0%
Phosphorus, Dissolved (mg/l)	0.02	23	-----	n.d.	n.d.	0.05	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	23	-----	0.04	n.d.	0.11	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	23	-----	n.d.	n.d.	0.03	-----	-----	-----
Sulfate (mg/l)	1	23	208	206	180	270	875(2,5), 500(2,7)	0	0%
Suspended Solids, Total (mg/l)	4	23	-----	n.d.	n.d.	15	158(1,5), 90(1,7)	0	0%
Microcystin, Total (ug/l)	0.2	12	-----	n.d.	n.d.	0.3	-----	-----	-----

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for the protection of warmwater permanent fish life propagation waters.
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of immersion and limited contact recreation waters (applies only to epilimnion and metalimnion if water body stratified).
- (4) Criteria for the protection of commerce and industry waters.
- (5) Daily maximum criterion (monitoring results directly comparable to criterion).
- (6) Daily minimum criterion (monitoring results directly comparable to criterion).
- (7) 30-day average criterion (monitoring results not directly comparable to criterion).
- (8) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5 C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1 C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5 C occurs over a 1-meter depth increment.

Plate 253. Summary of monthly (June through September) water quality conditions monitored in Fort Randall Reservoir near Snake Creek (site FTRLK0924DW) during the 3-year period 2006 through 2008

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	12	1354.0	1354.4	1347.1	1362.0	-----	-----	-----
Water Temperature (C)	0.1	214	22.2	22.9	11.6	27.2	27[1,5]	1	<1%
Dissolved Oxygen (mg/l)	0.1	214	7.9	7.9	3.2	9.5	5[1,6]	19	6%
Dissolved Oxygen (% Sat.)	0.1	214	93.7	94.7	39.4	114.4	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	199	7.9	7.9	6.2	9.5	5[3,6]	1	<1%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	15	7.2	6.7	3.2	9.2	5[1,6]	1	7%
Specific Conductance (umho/cm)	1	214	721	720	693	738	-----	-----	-----
pH (S.U.)	0.1	196	8.4	8.5	7.8	8.6	6.5[1,2,6], 9.0[1,2,5], 9.5[4,5]	0	0%
Turbidity (NTUs)	1	213	9	8	2	58	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	214	330	314	255	498	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	211	3	2	n.d.	21	-----	-----	-----
Secchi Depth (in)	1	12	47	47	25	84	-----	-----	-----

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. The mean is not reported if 20% or more of the observations were nondetects. The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.
- (1) Criteria for the protection of warmwater permanent fish life propagation waters.
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of immersion and limited contact recreation waters (applies only to epilimnion and metalimnion if water body stratified).
- (4) Criteria for the protection of commerce and industry waters.
- (5) Daily maximum criterion (monitoring results directly comparable to criterion).
- (6) Daily minimum criterion (monitoring results directly comparable to criterion).

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5 C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1 C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0 5 C occurs over a 1-meter depth increment

Plate 254. **S**ummary of monthly (June through September) water quality conditions monitored in Fort Randall Reservoir near Elm Creek (Site FTRLK0940DW) during the 3-year period 2006 through 2008.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	10	1354.8	1354.7	1347.1	1361.9	-----	-----	-----
Water Temperature (C)	0.1	53	22.8	24.6	13.8	26.4	27[1,5]	0	0%
Dissolved Oxygen (mg/l)	0.1	53	8 3	8.1	7.6	9.2	5[1,6]	0	0%
Dissolved Oxygen (% Sat.)	0.1	53	100 3	99.4	82.1	115.1	----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	53	8 3	8.1	7.6	9.2	5[3,6]	0	0%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	0[F]	-----	-----	-----	-----	5[1,6]	-----	-----
Specific Conductance (umho/cm)	1	53	721	719	701	738	-----	-----	-----
pH (S.U.)	0.1	47	8.4	8.5	8.1	8.6	6.5[1,2,6], 9.0[1,2,5], 9.5[4,5]	0	0%
Turbidity (NTUs)	1	53	28	14	3	284	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	53	316	312	265	400	-----	-----	-----
Secchi Depth (in.)	1	9	26	24	7	52	-----	-----	-----
Alkalinity, Total (mg/l)	7	20	155	158	131	170	-----	-----	-----
Ammonia, Total (mg/l)	0.02	20	-----	0.02	n.d.	0.24	3.2[1,5,8], 0.54[1,7,8]	0	0%
Carbon, Total Organic (mg/l)	0.05	18	3 1	3.2	1.7	4.0	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	20	14	14	4	30	-----	-----	-----
Chloride (mg/l)	1	20	11	11	9	12	175[1,5], 100[1,7], 438[2,5], 250[2,7]	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	53	4	4	n.d.	11	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	10	7	8	n.d.	10	-----	-----	-----
Dissolved Solids, Total (mg/l)	4	20	470	467	444	540	1,750[2,5], 1,000[2,7], 3,500[4,5], 2,000[4,7]	0	0%
Iron, Total (ug/l)	40	17	851	391	110	4,321	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	20	0 5	0.4	n.d.	1.0	-----	-----	-----
Manganese, Total (ug/l)	2	17	48	30	10	193	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	20	-----	n.d.	n.d.	0.30	10[2,5]	0	0%
Phosphorus, Dissolved (mg/l)	0.02	20	-----	n.d.	n.d.	0.04	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	20	0.05	0.05	n.d.	0.13	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	20	-----	n.d.	n.d.	0.03	-----	-----	-----
Sulfate (mg/l)	1	20	205	204	176	230	875[2,5], 500[2,7]	0	0%
Suspended Solids, Total (mg/l)	4	20	21	7	n.d.	140	158[1,5], 90[1,7]	0, 2	0%, 10%
Microcystin, Total (ug/l)	0.2	10	-----	n.d.	n.d.	0.2	-----	-----	-----

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.
- (1) Criteria for the protection of warmwater permanent fish life propagation waters.
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of immersion and limited contact recreation waters (applies only to epilimnion and metalimnion if water body stratified).
- (4) Criteria for the protection of commerce and industry waters.
- (5) Daily maximum criterion (monitoring results directly comparable to criterion).
- (6) Daily minimum criterion (monitoring results directly comparable to criterion).
- (7) 30-day average criterion (monitoring results not directly comparable to criterion).
- (8) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5 C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1 C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5 C occurs over a 1-meter depth increment.

(F) Depth-profiles did not indicate the presence of a hypolimnion during monitored period. It is assumed that the water column experienced complete mixing due to shallower water depths during the monitored period.

Plate 255. Summary of monthly (June through September) water quality conditions monitored in Fort Randall Reservoir near the White River (site FTRLK0955DW) during the 3-year period 2006 through 2008.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	12	1354.0	1354 3	1347.1	1361.6	-----	-----	-----
Water Temperature (C)	0.1	50	22.6	24.4	14.9	26.0	27(1,5)	0	0%
Dissolved Oxygen (mg/l)	0.1	49	8.1	8 1	0.1	9.5	5(1,6)	19	6%
Dissolved Oxygen (% Sat.)	0.1	49	96.9	100.8	1.6	104.1	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	49	8.1	8 1	0.1	9.5	5(3,6)	0	0%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	0[F]	-----	-----	-----	-----	5(1,6)	-----	-----
Specific Conductance (umho/cm)	1	50	706	704	559	735	-----	-----	-----
pH (S.U.)	0.1	45	8.4	8 5	8.0	8.7	6.5(1,2,6), 9.0(1,2,5), 9.5(4,5)	0	0%
Turbidity (NTUs)	1	47	33	20	8	210	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	50	354	311	250	614	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	49	5	4	n.d.	12	-----	-----	-----
Secchi Depth (in)	1	11	20	18	11	32	-----	-----	-----

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. The mean is not reported if 20% or more of the observations were nondetects. The mean value reported for pH is an arithmetic mean based on measured values (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.
- (1) Criteria for the protection of warmwater permanent fish life propagation waters.
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of immersion and limited contact recreation waters (applies only to epilimnion and metalimnion if water body stratified).
- (4) Criteria for the protection of commerce and industry waters.
- (5) Daily maximum criterion (monitoring results directly comparable to criterion).
- (6) Daily minimum criterion (monitoring results directly comparable to criterion).

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5 C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1 C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0 5 C occurs over a 1-meter depth increment.

(F) Depth-profiles did not indicate the presence of a hypolimnion during monitored period. It is assumed that the water column experienced complete mixing due to shallower water depths during the monitored period.

Plate 256. **S**ummary of monthly (June through September) water quality conditions monitored in Fort Randall Reservoir near Chamberlin, SD (Site FTRLK0968DW) during the 3-year period 2006 through 2008.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	12	1354.0	1354.3	1347.1	1361.6	-----	-----	-----
Water Temperature (C)	0.1	75	22.1	23.6	15.6	28.3	27[1,5]	1	1%
Dissolved Oxygen (mg/l)	0.1	75	8.4	8.3	7.6	9.4	5[1,6]	0	0%
Dissolved Oxygen (% Sat.)	0.1	75	99.7	99.6	92.4	112.1	----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	75	8.4	8.3	7.6	9.4	5[1,6]	0	0%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	0[F]	-----	-----	-----	-----	5[1,6]	-----	-----
Specific Conductance (umho/cm)	1	75	715	720	672	746	-----	-----	-----
pH (S.U.)	0.1	69	8.5	8.4	8.1	8.7	6.5[1,2,6], 9.0[1,2,5], 9.5[4,5]	0	0%
Turbidity (NTUs)	1	75	17	12	6	40	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	75	340	308	258	545	-----	-----	-----
Secchi Depth (in.)	1	11	23	24	14	32	-----	-----	-----
Alkalinity, Total (mg/l)	7	24	158	160	140	170	-----	-----	-----
Ammonia, Total (mg/l)	0.02	24	-----	0.03	n.d.	0.22	3 9[1,5,8], 0.69[1,7,8]	0	0%
Carbon, Total Organic (mg/l)	0.05	22	2.9	2.9	1.5	5.3	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	24	11	12	n.d.	20	-----	-----	-----
Chloride (mg/l)	1	24	11	11	9	13	175[1,5], 100[1,7], 438[2,5], 250[2,7]	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	74	4	4	1	12	-----	-----	-----
Chlorophyll *a* (ug/l) – Lab Determined	1	11	7	6	1	16	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	24	490	483	450	582	1,750[2,5], 1,000[2,7], 3,500[4,5], 2,000[4,7]	0	0%
Iron, Total (ug/l)	40	20	453	448	130	830	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	24	0.6	0.4	0.2	2.5	-----	-----	-----
Manganese, Total (ug/l)	2	20	61	60	30	110	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	24	-----	n.d.	n.d.	0.11	10[2,5]	0	0%
Phosphorus, Dissolved (mg/l)	0.02	24	-----	0.02	n.d.	0.08	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	24	0.07	0.05	n.d.	0.31	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	24	-----	n.d.	n.d.	0.04	-----	-----	-----
Sulfate (mg/l)	1	24	201	202	173	230	875[2,5], 500[2,7]	0	0%
Suspended Solids, Total (mg/l)	4	24	12	12	n.d.	27	158[1,5], 90[1,7]	0	0%
Microcystin, Total (ug/l)	0.2	12	-----	n.d.	n.d.	0.3	-----	-----	-----

n.d. = Not detected.

[A] Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

[B] Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), Specific Conductance, pH, Oxidation-Reduction Potential, and Secchi Depth are resolution limits for field measured parameters.

[C] Nondetect values set to 0 to calculate mean. If 20% or more of observations were nondetects, mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

[D] Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- [1] Criteria for the protection of warmwater permanent fish life propagation waters.
- [2] Criteria for the protection of domestic water supply waters.
- [3] Criteria for the protection of immersion and limited contact recreation waters (applies only to epilimnion and metalimnion if water body stratified).
- [4] Criteria for the protection of commerce and industry waters.
- [5] Daily maximum criterion (monitoring results directly comparable to criterion).
- [6] Daily minimum criterion (monitoring results directly comparable to criterion).
- [7] 30-day average criterion (monitoring results not directly comparable to criterion).
- [8] Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.

[E] A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5 C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1 C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5 C occurs over a 1-meter depth increment.

[F] Depth-profiles did not indicate the presence of a hypolimnion during monitored period. It is assumed that the water column experienced complete mixing due to shallower water depths during the monitored period.

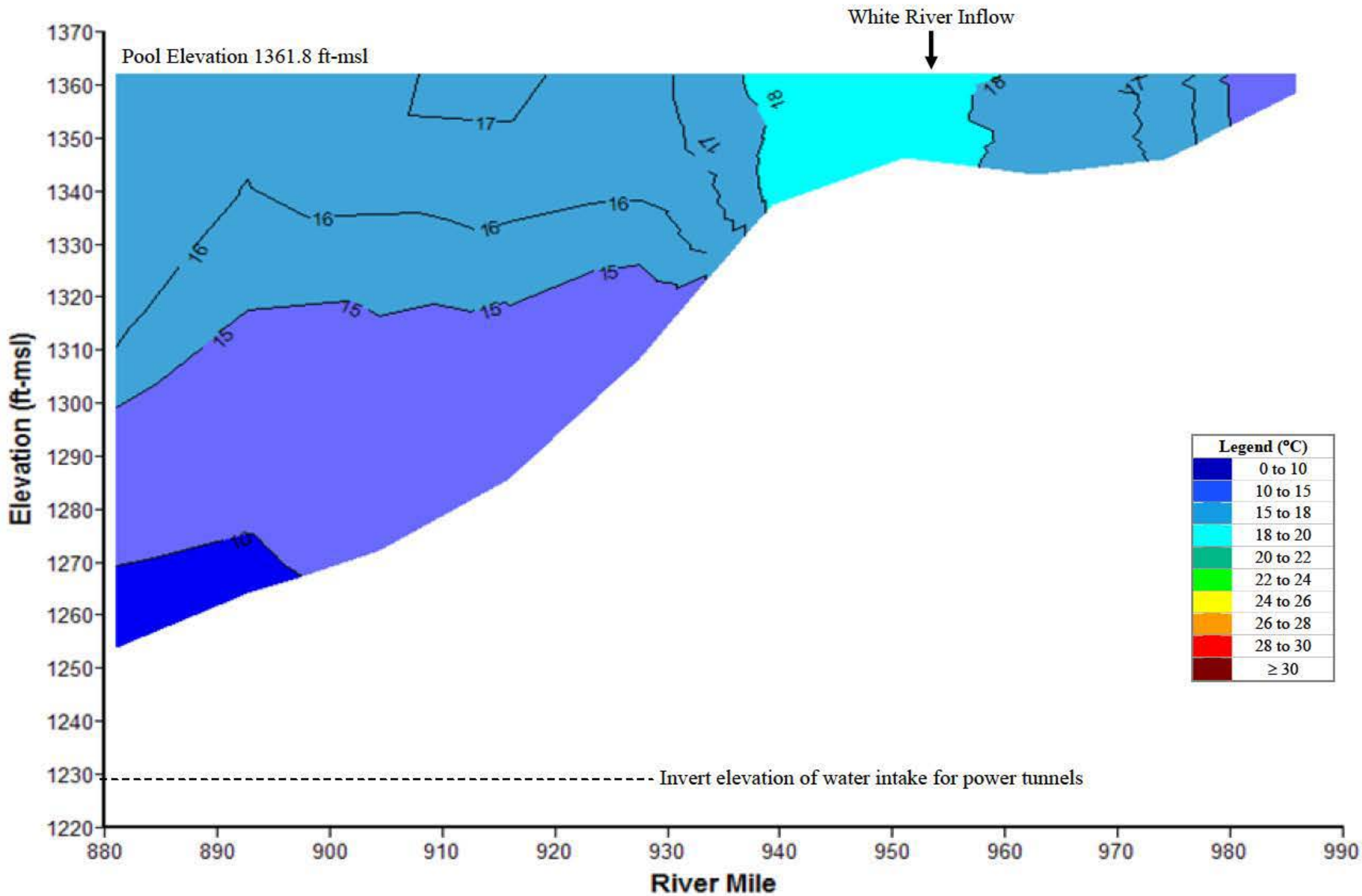


Plate 257. Longitudinal water temperature (°C) contour plot of Fort Randall Reservoir based on depth-profile water temperatures measured along the submerged old Missouri River channel at River Miles 880, 892, 911, 924, 940, 955, and 987 on June 9, 2008.

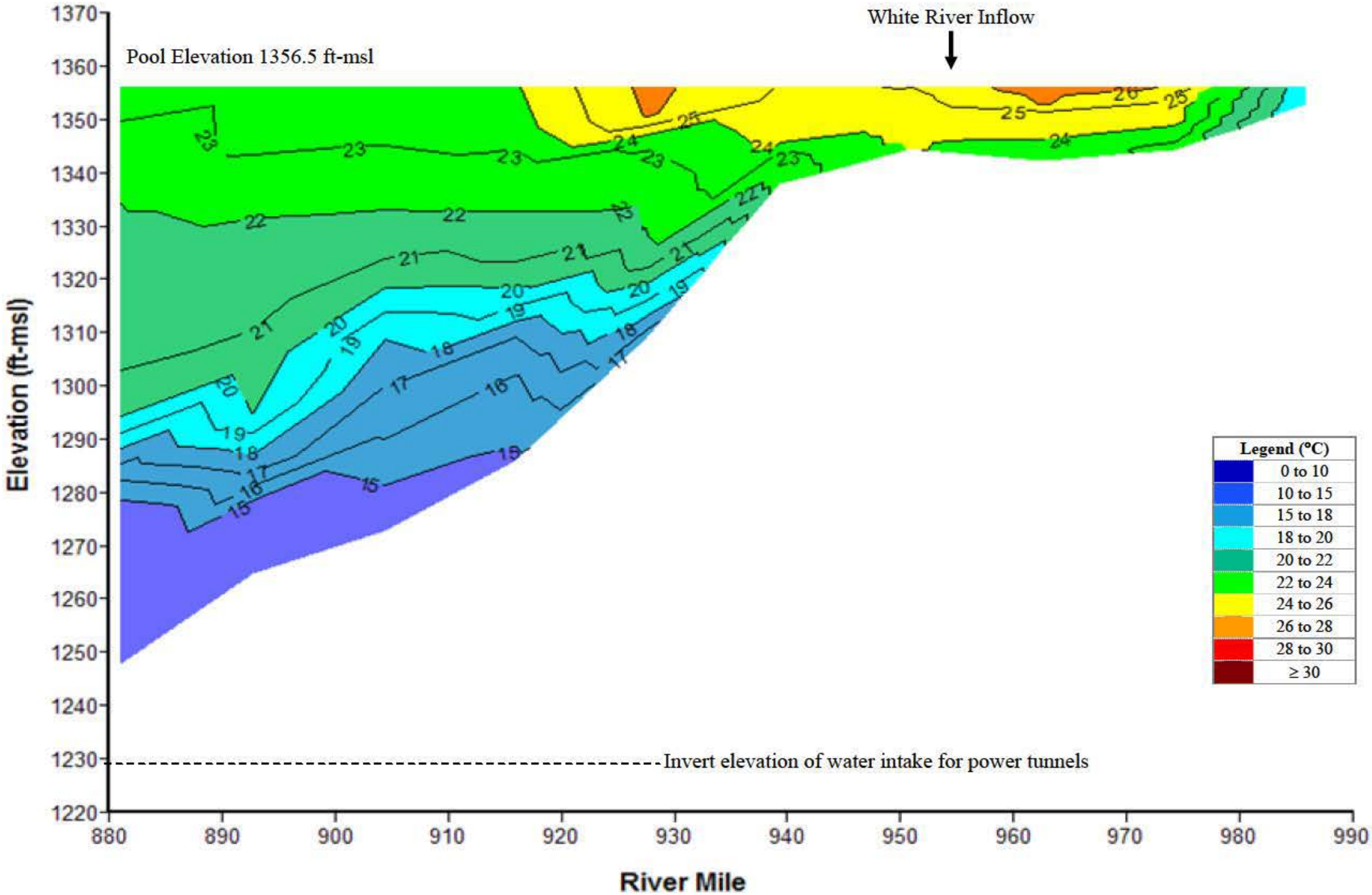


Plate 258. Longitudinal water temperature (°C) contour plot of Fort Randall Reservoir based on depth-profile water temperatures measured along the submerged old Missouri River channel at River Miles 880, 892, 911, 924, 940, 955, and 987 on July 15, 2008.

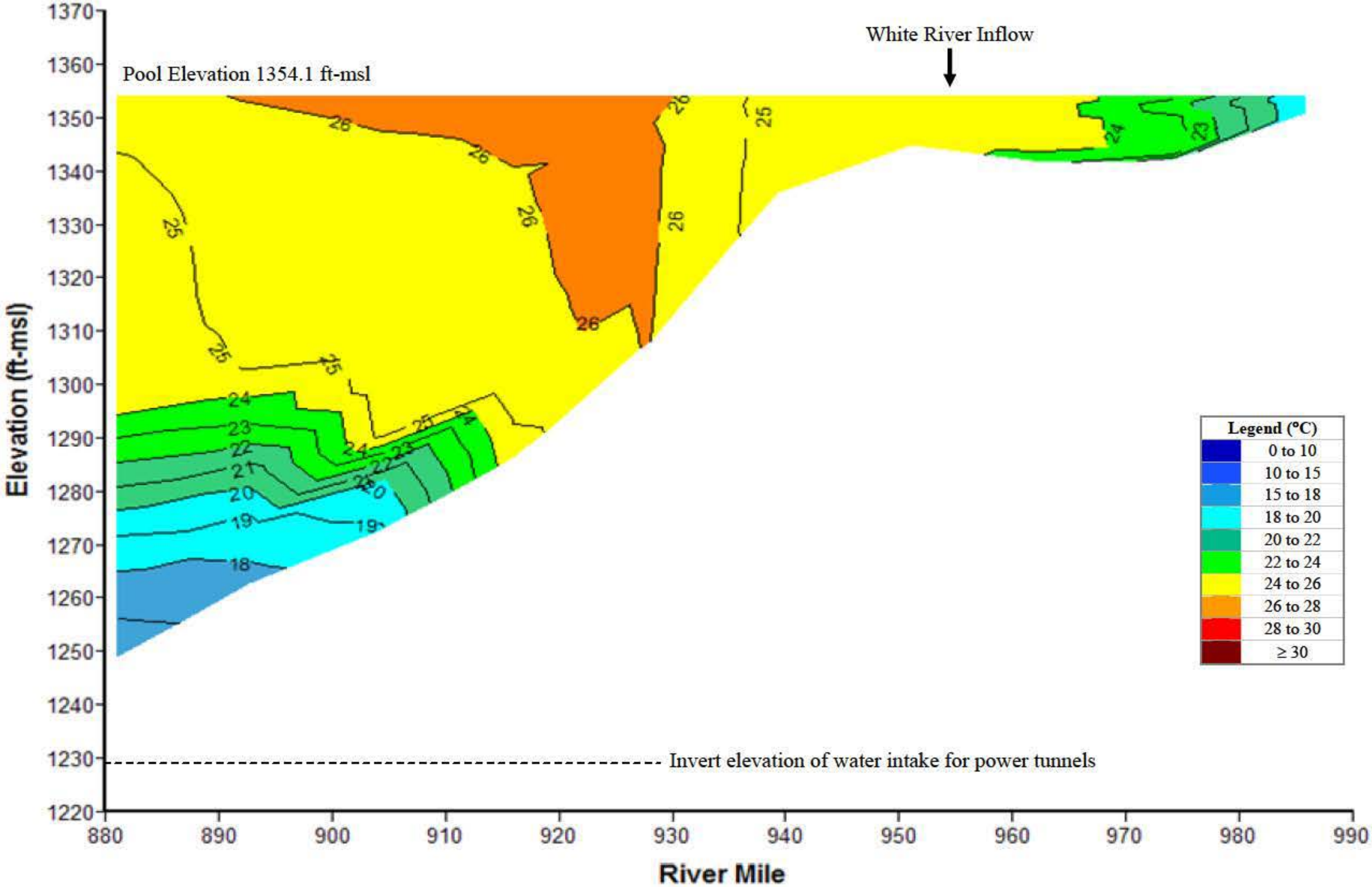


Plate 259. Longitudinal water temperature (°C) contour plot of Fort Randall Reservoir based on depth-profile water temperatures measured along the submerged old Missouri River channel at River Miles 880, 892, 911, 924, 940, 955, and 987 on August 12, 2008.

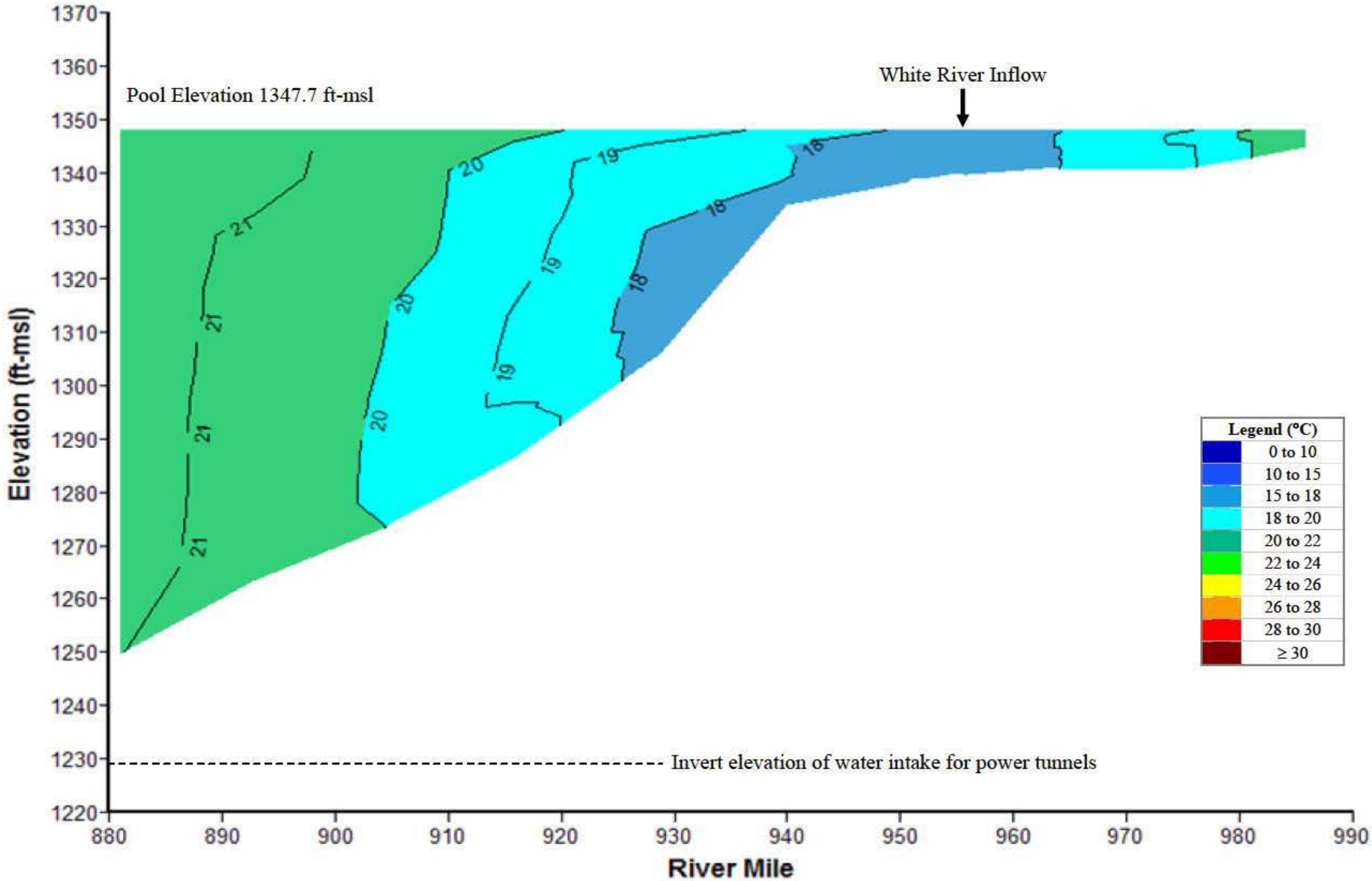


Plate 260. Longitudinal water temperature (°C) contour plot of Fort Randall Reservoir based on depth-profile water temperatures measured along the submerged old Missouri River channel at River Miles 880, 892, 911, 924, 940, 955, and 987 on September 15, 2008.

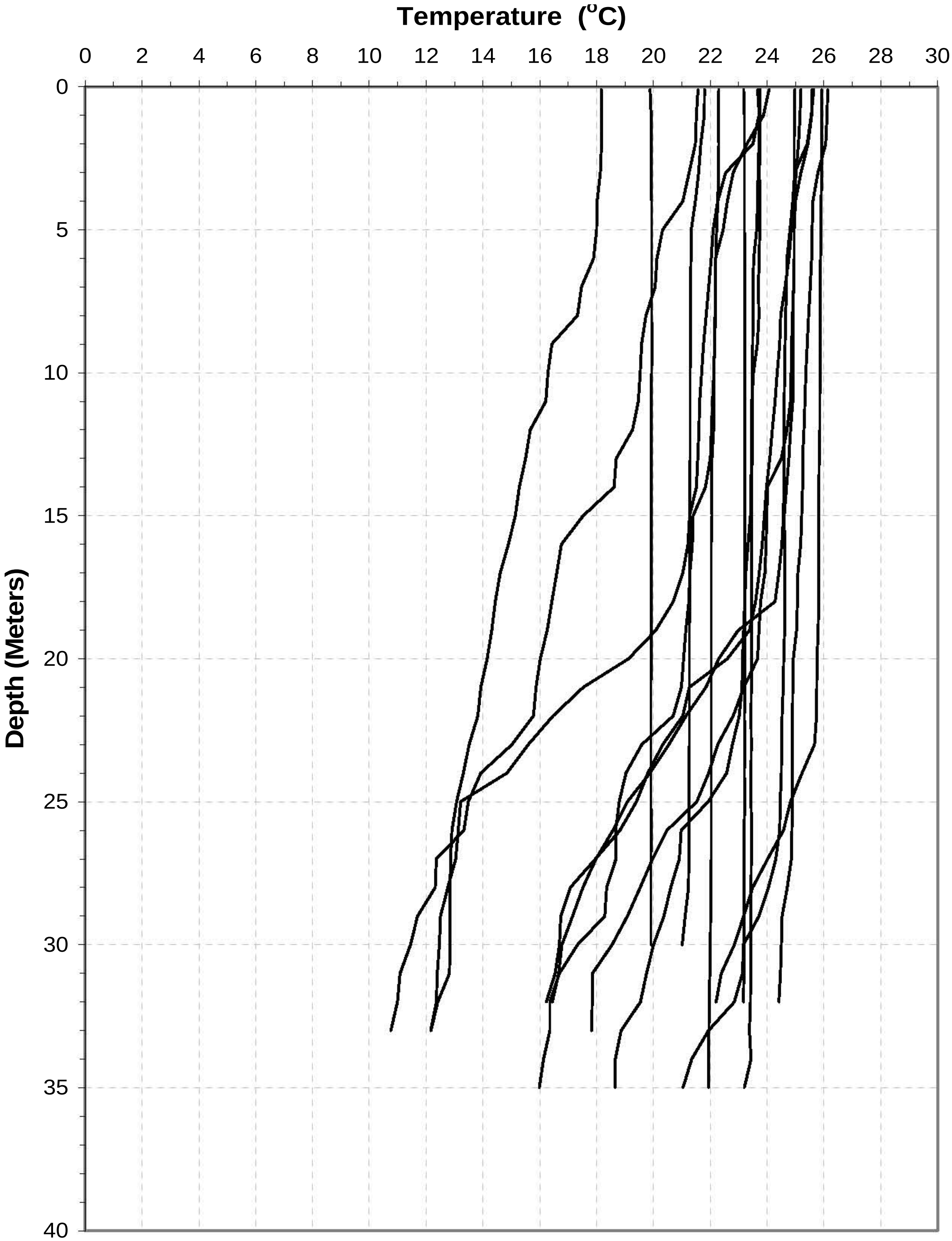


Plate 261. Temperature depth profiles for Fort Randall Reservoir generated from data collected at the near-dam, deepwater ambient monitoring site (i.e., site FTRLK0880A) during the summer months over the 5-year period of 2004 to 2008.

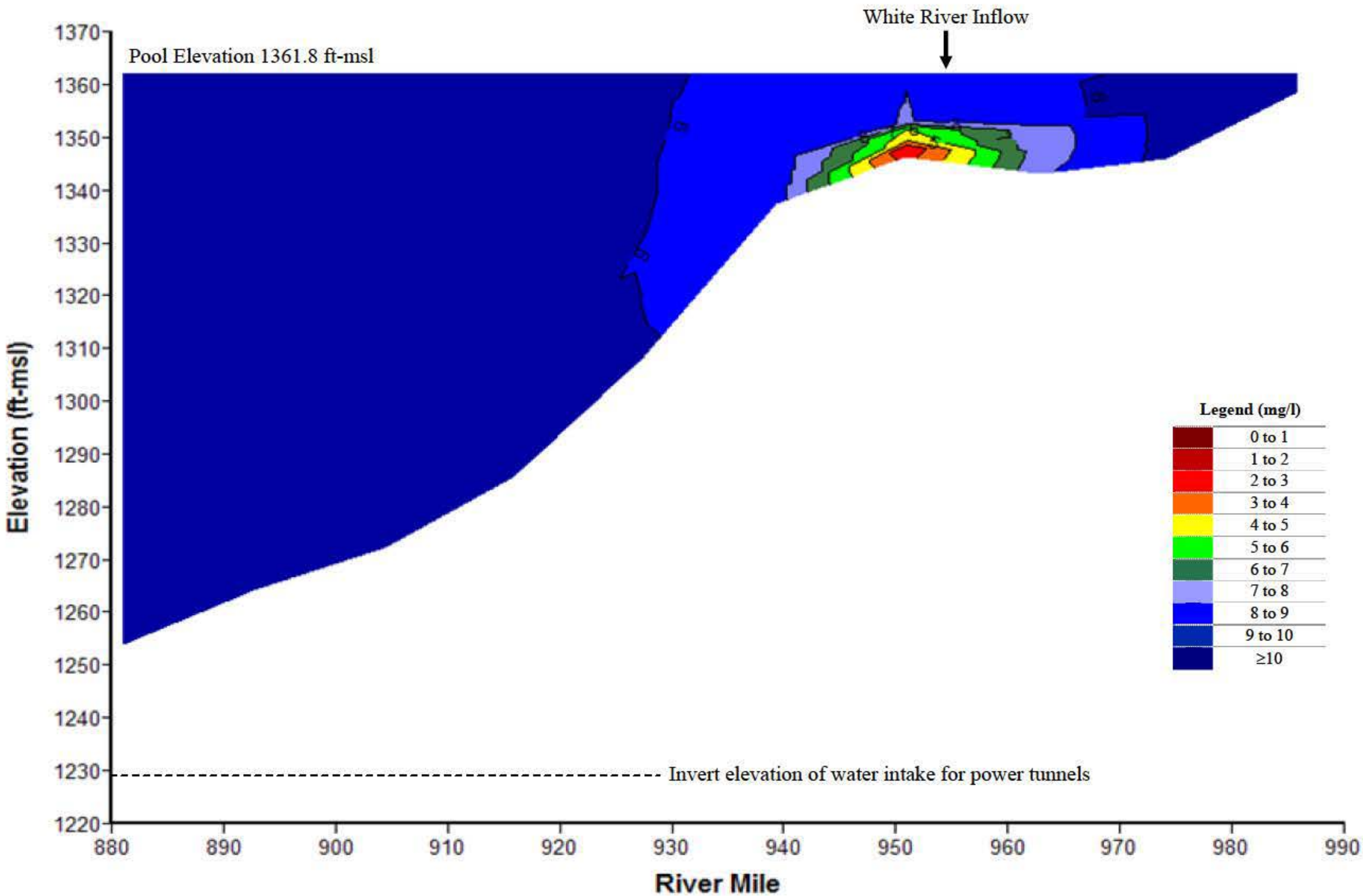


Plate 262. Longitudinal dissolved oxygen (mg/l) contour plot of Fort Randall Reservoir based on depth-profile dissolved oxygen concentrations measured along the submerged old Missouri River channel at River Miles 880, 892, 911, 924, 940, 955, and 987 on June 9, 2008.

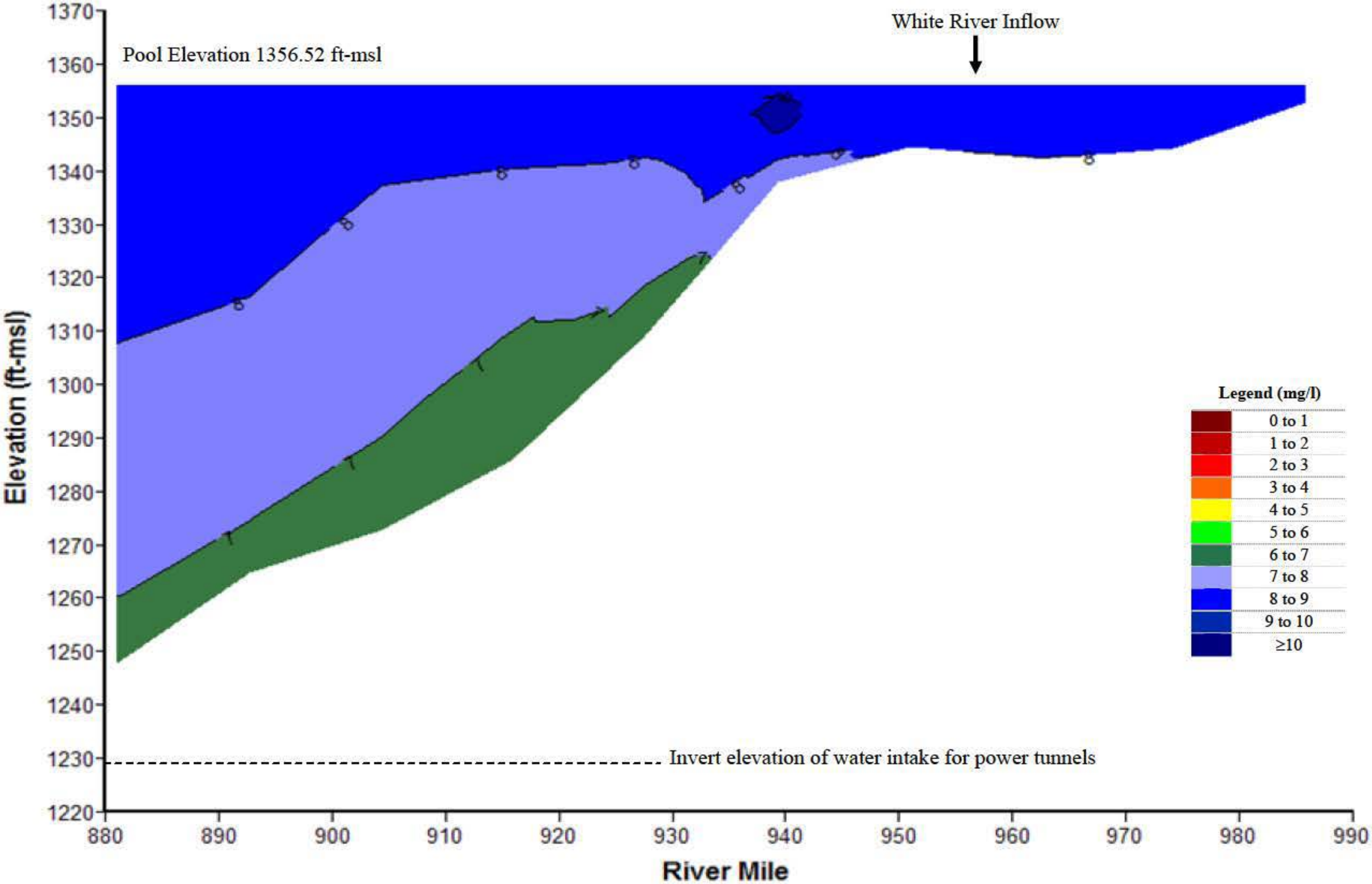


Plate 263. Longitudinal dissolved oxygen (mg/l) contour plot of Fort Randall Reservoir based on depth-profile dissolved oxygen concentrations measured along the submerged old Missouri River channel at River Miles 880, 892, 911, 924, 940, 955, and 987 on July 15, 2008.

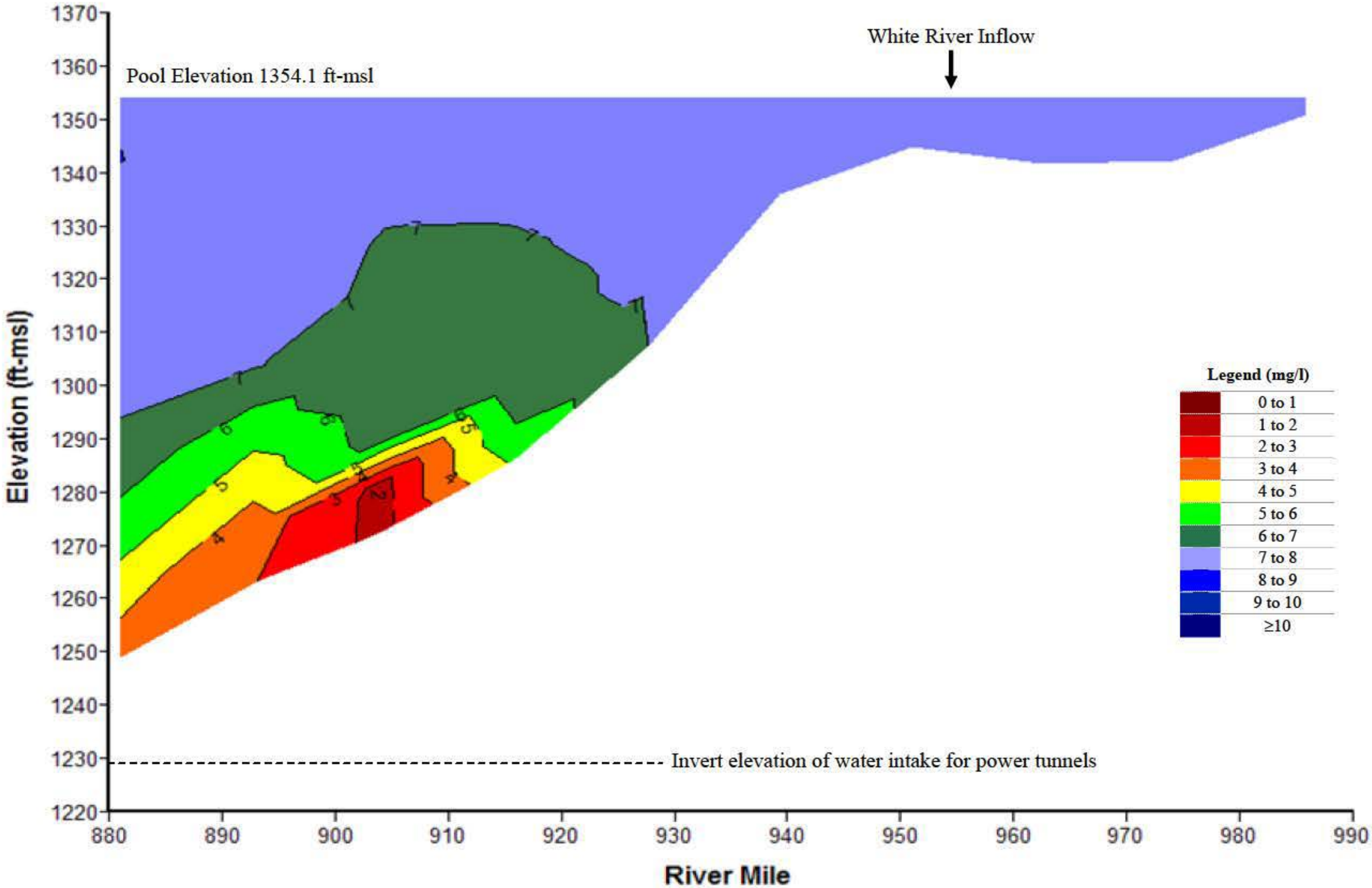


Plate 264. Longitudinal dissolved oxygen (mg/l) contour plot of Fort Randall Reservoir based on depth-profile dissolved oxygen concentrations measured along the submerged old Missouri River channel at River Miles 880, 892, 911, 924, 940, 955, and 987 on August 12, 2008.

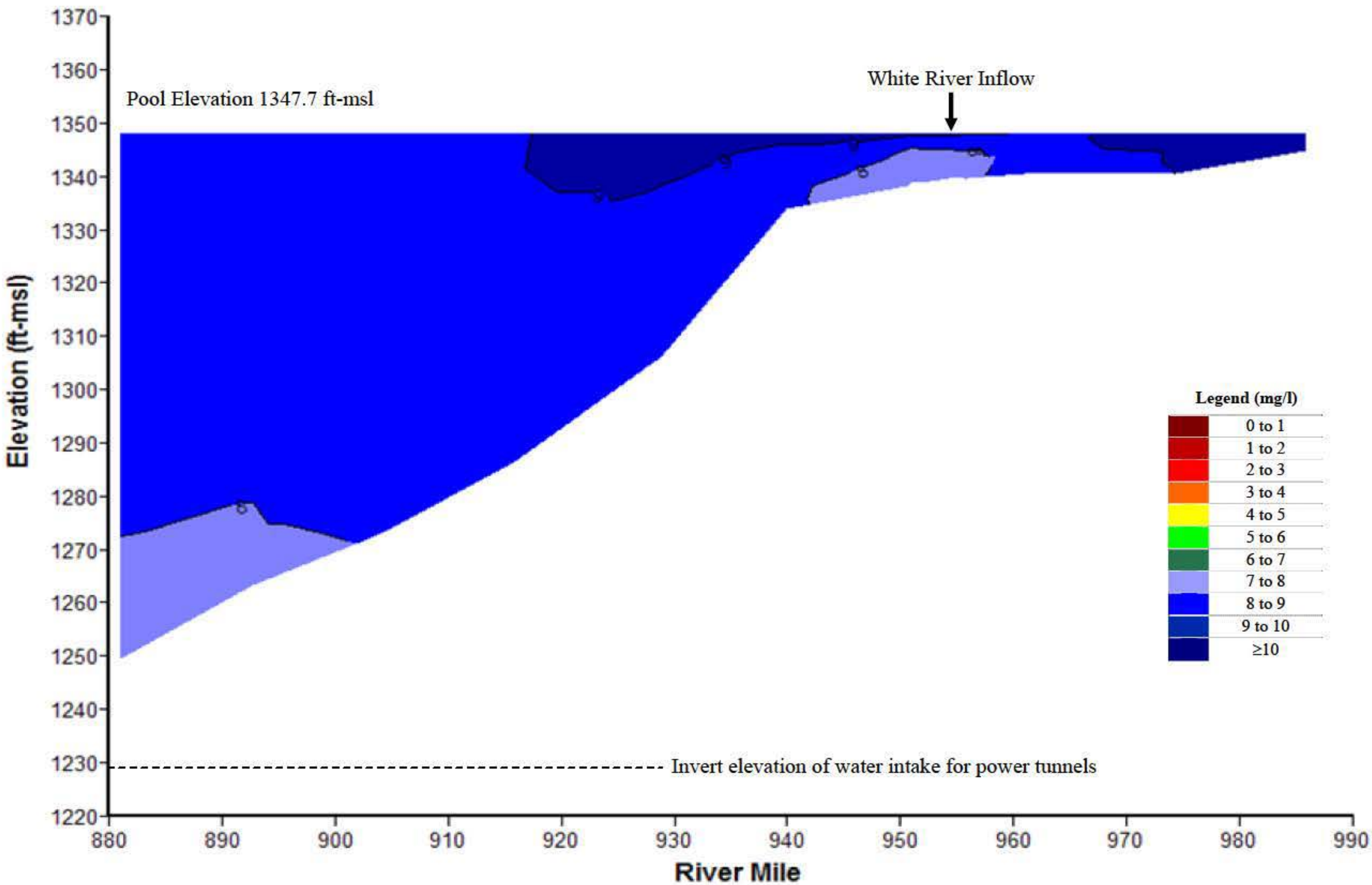


Plate 265. Longitudinal dissolved oxygen (mg/l) contour plot of Fort Randall Reservoir based on depth-profile dissolved oxygen concentrations measured along the submerged old Missouri River channel at River Miles 880, 892, 911, 924, 940, 955, and 987 on September 15, 2008.

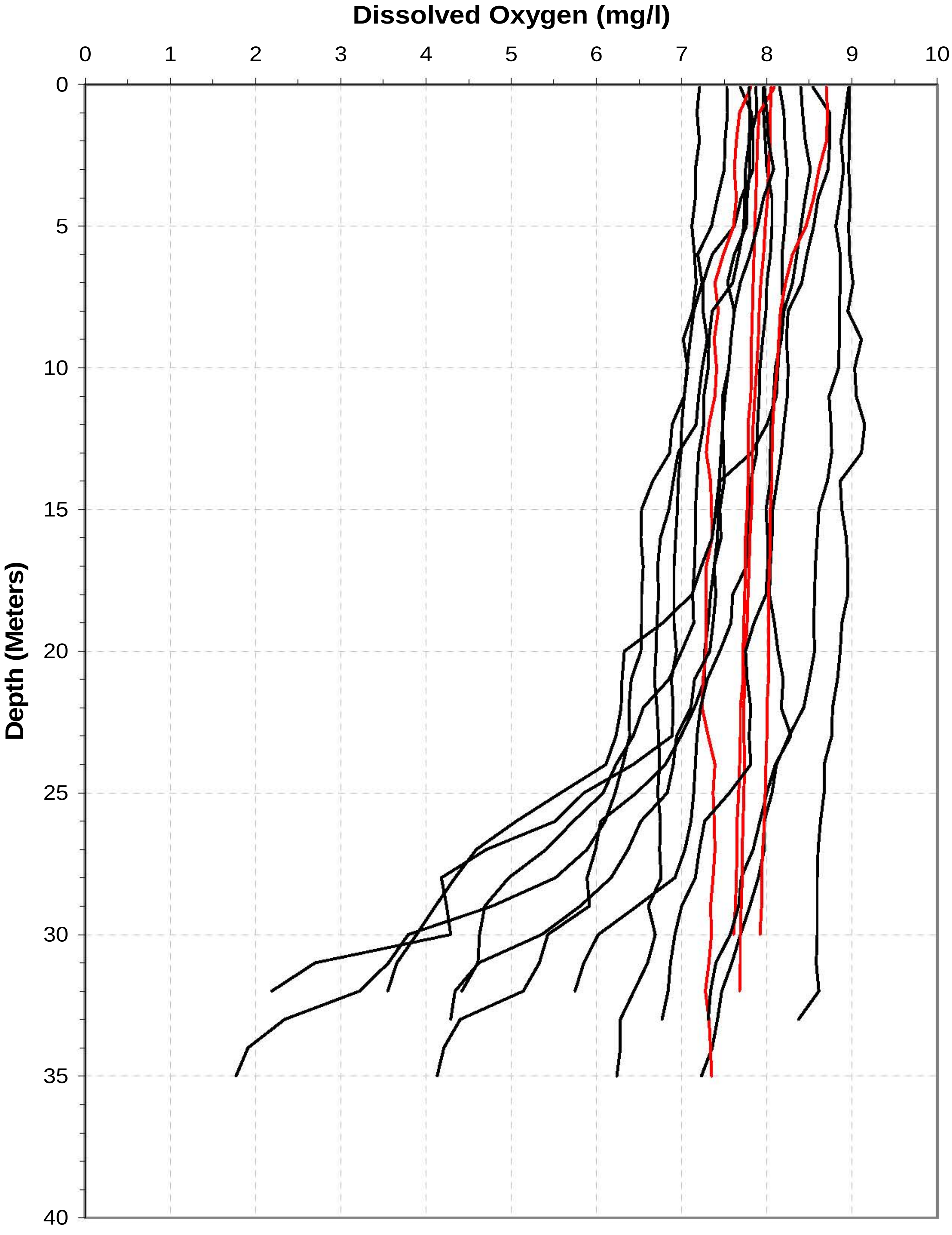


Plate 266. Dissolved oxygen depth profiles for Fort Randall Reservoir generated from data collected at the near-dam, deepwater ambient monitoring site (i.e., site FTRLK0880A) during the summer months over the 5-year period of 2004 to 2008.
(Note: Red profile plots were measured in the month of September.)

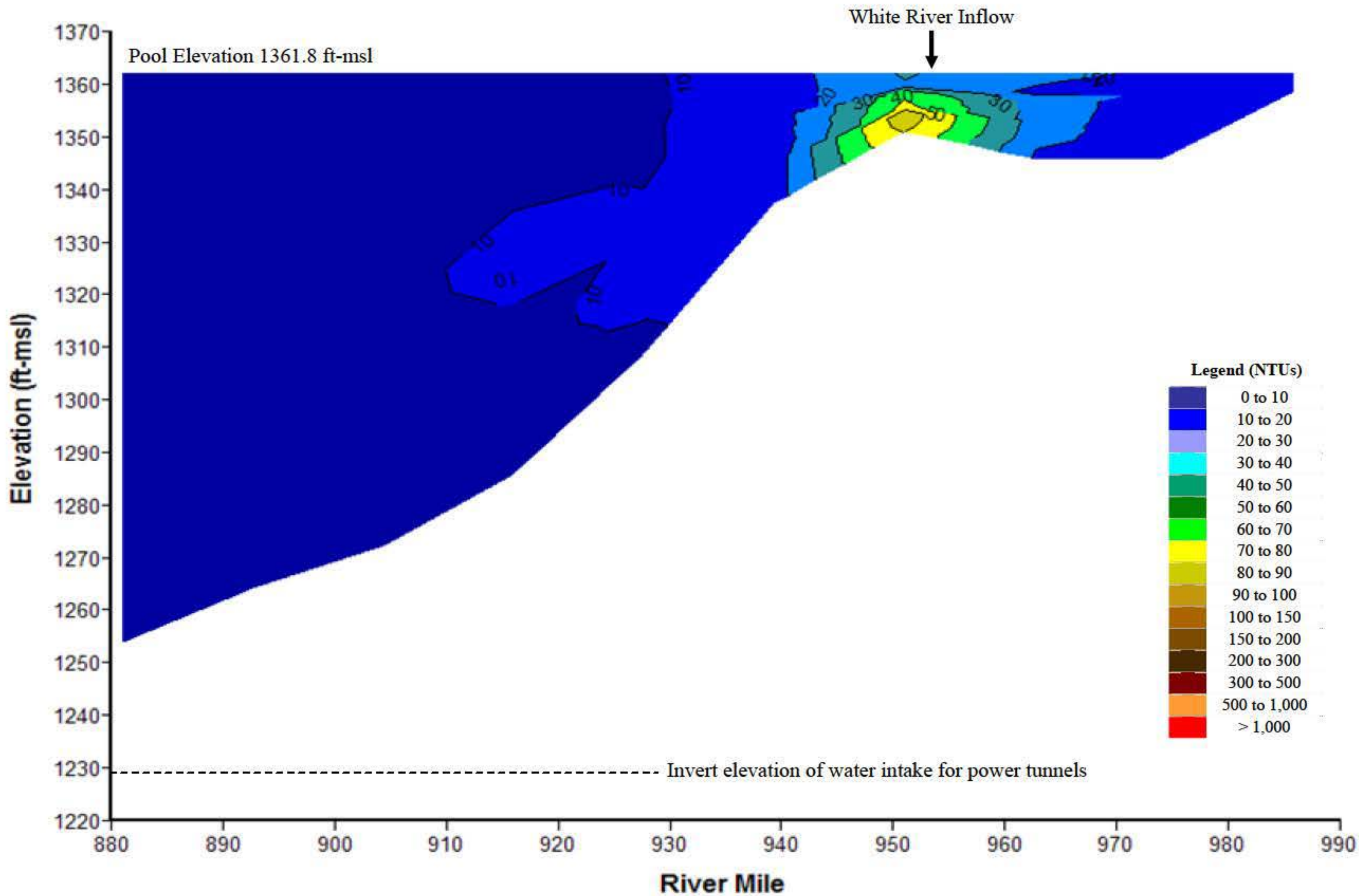


Plate 267. Longitudinal turbidity (NTU) contour plot of Fort Randall Reservoir based on depth-profile turbidity levels measured along the submerged old Missouri River channel at River Miles 880, 892, 911, 924, 940, 955, and 987 on June 9, 2008.

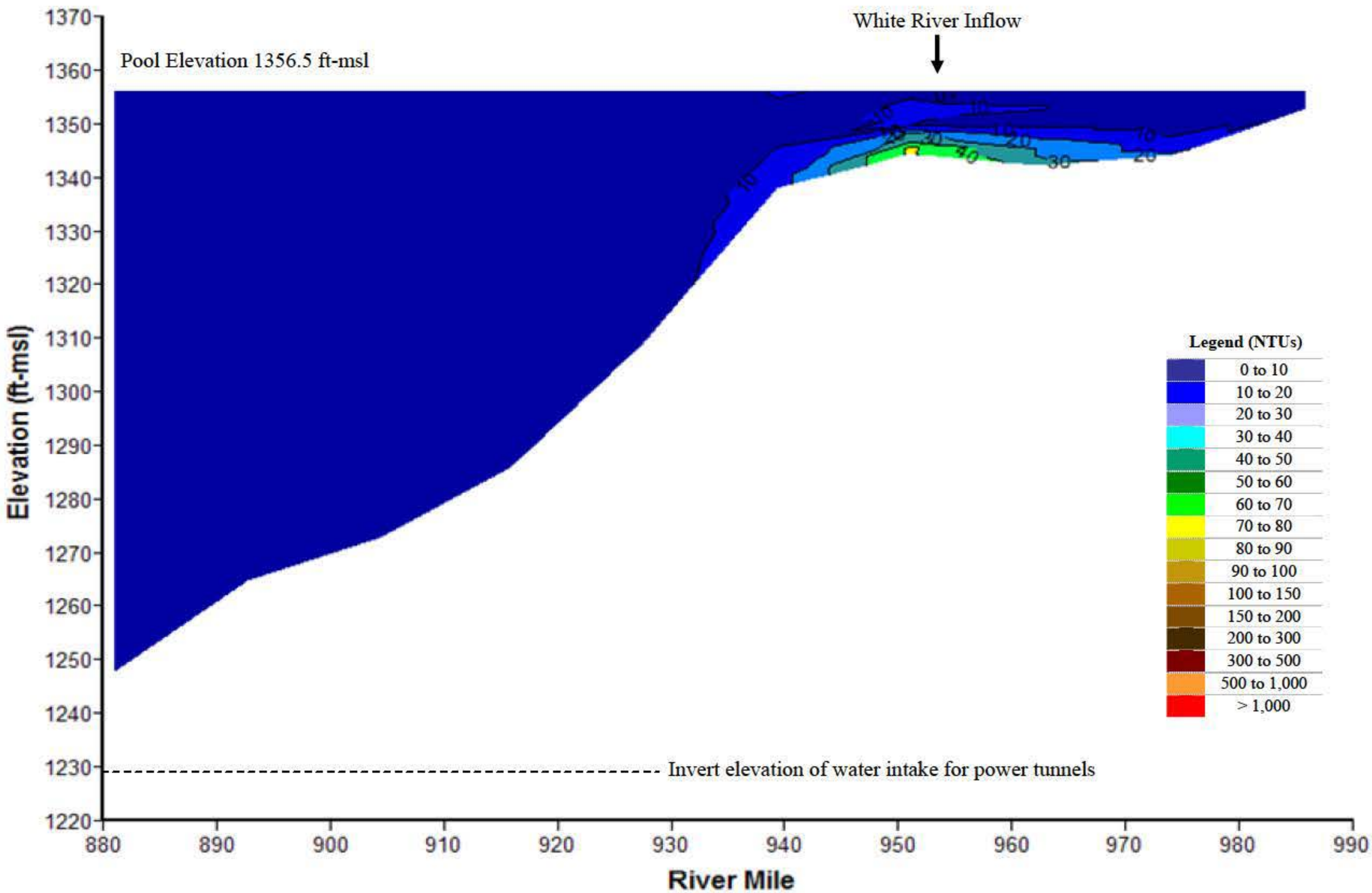


Plate 268. Longitudinal turbidity (NTU) contour plot of Fort Randall Reservoir based on depth-profile turbidity levels measured along the submerged old Missouri River channel at River Miles 880, 892, 911, 924, 940, 955, and 987 on July 15, 2008.

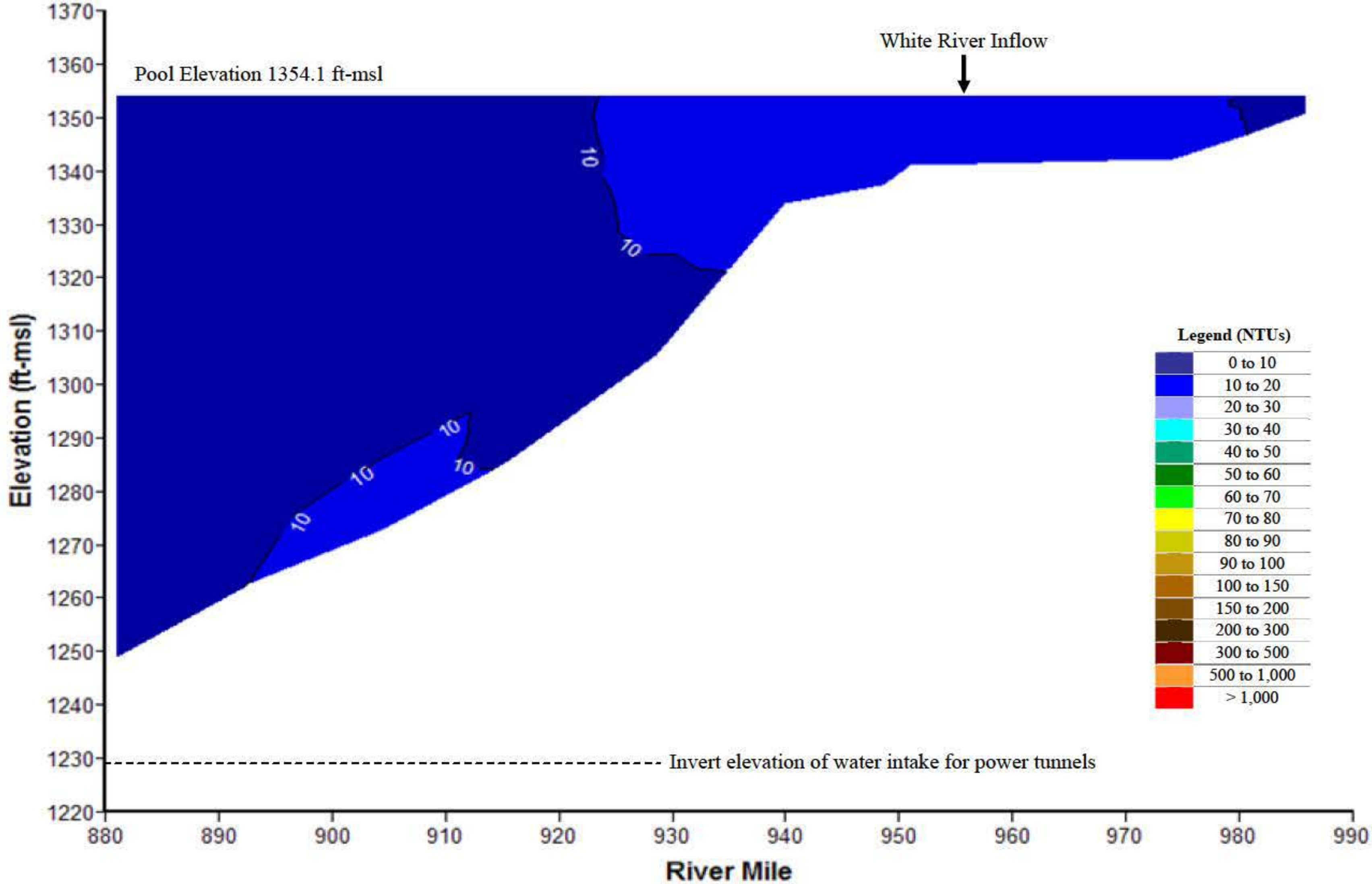


Plate 269. Longitudinal turbidity (NTU) contour plot of Fort Randall Reservoir based on depth-profile turbidity levels measured along the submerged old Missouri River channel at River Miles 880, 892, 911, 924, 940, 955, and 987 on August 12, 2008.

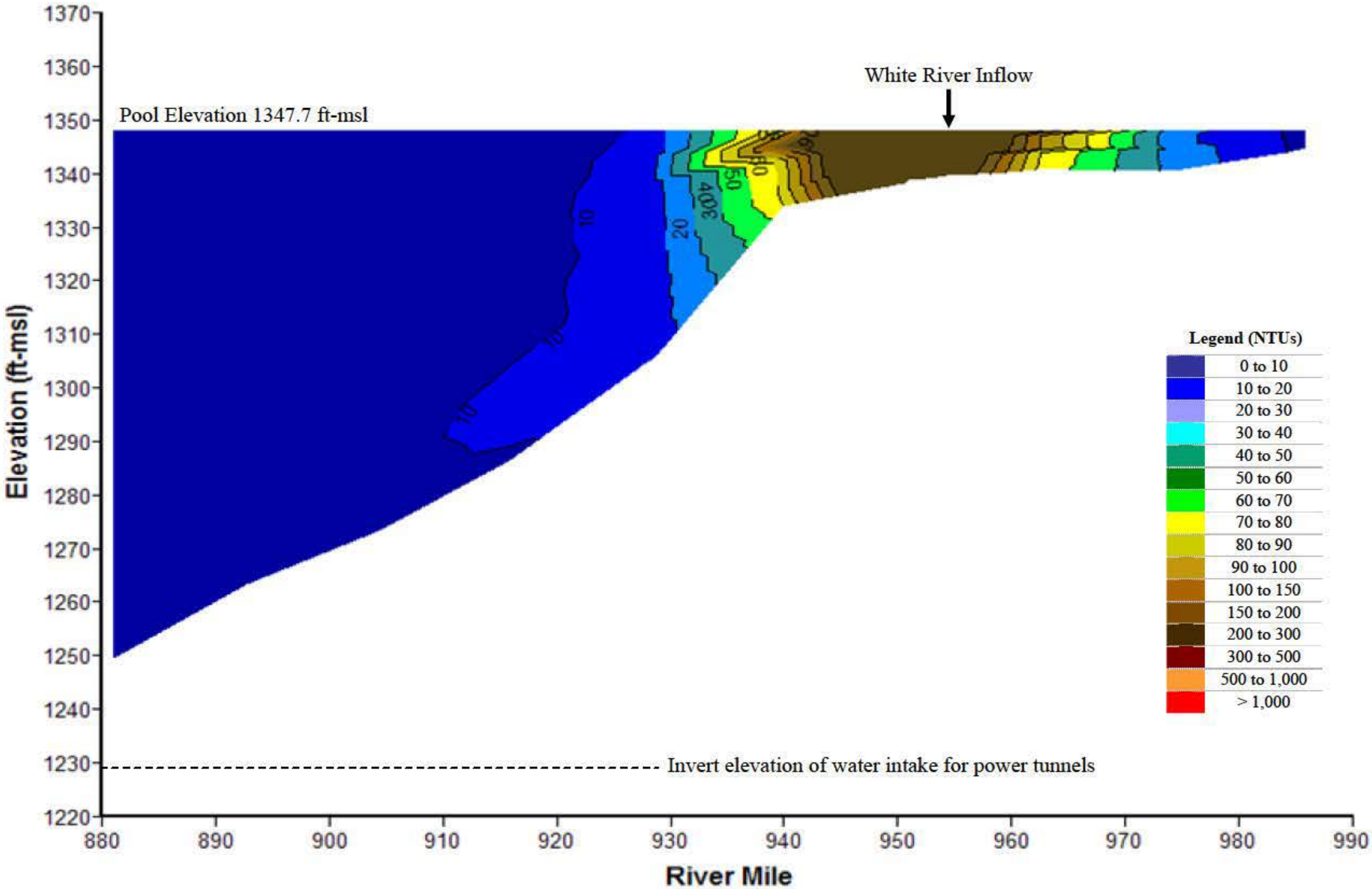


Plate 270. Longitudinal turbidity (NTU) contour plot of Fort Randall Reservoir based on depth-profile turbidity levels measured along the submerged old Missouri River channel at River Miles 880, 892, 911, 924, 940, 955, and 987 on September 15, 2008.

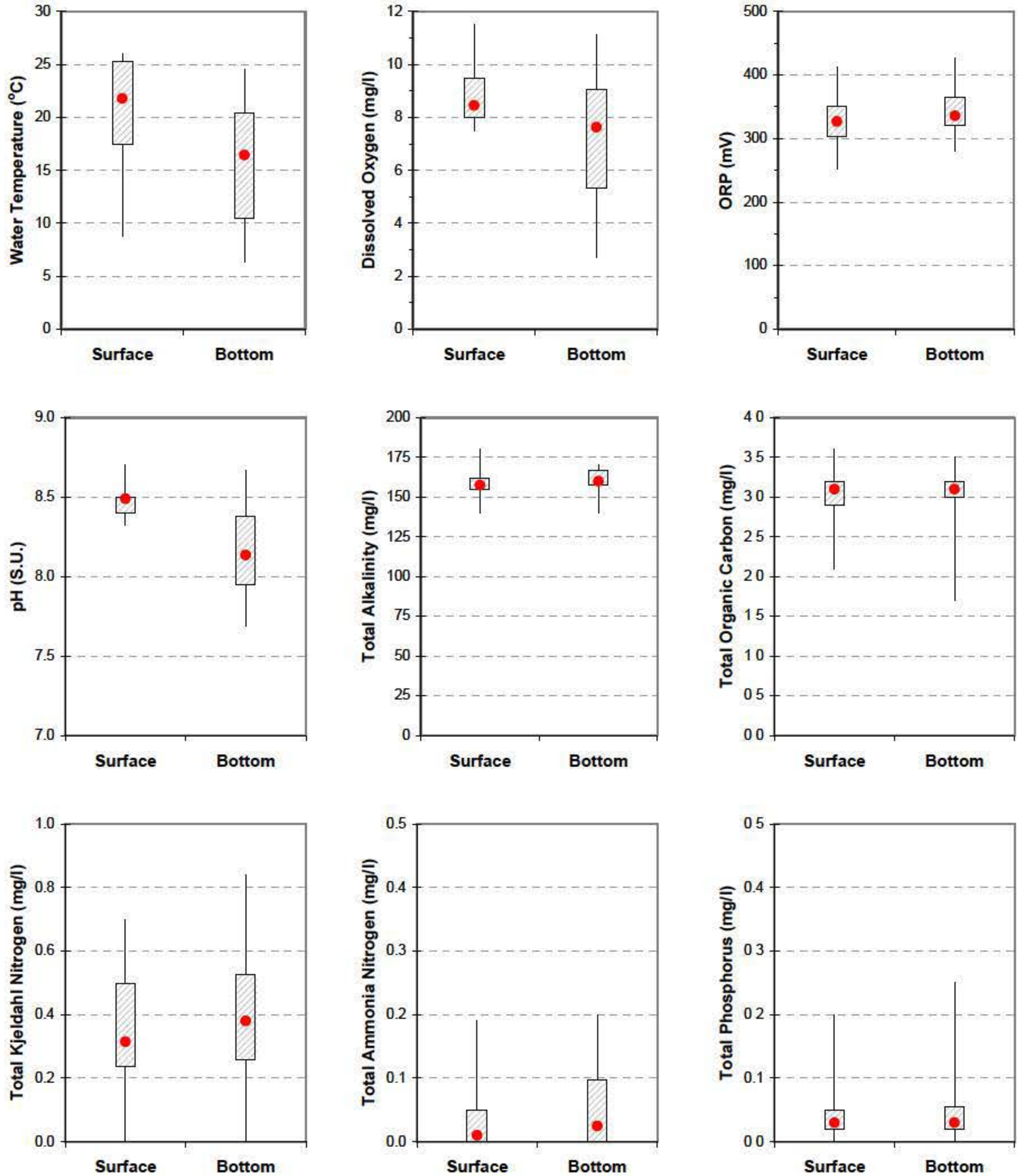


Plate 271. Box plots comparing paired surface and bottom water temperature, dissolved oxygen, oxidation-reduction potential, pH, alkalinity, total organic carbon, total Kjeldahl nitrogen, total ammonia nitrogen, and total phosphorus measurements taken in Fort Randall Reservoir at site FTRLK0880A during the summer months of 2004 through 2008.
(Box plots display minimum, 25th percentile, 75th percentile, and maximum. Median value is indicated by the red dot.)

Plate 272. Total biovolume, number of genera present, and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected in Fort Randall Reservoir at site FTRLK0880A during the 5-year period 2004 through 2008.

Date	Total Sample Biovolume (um^3)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta		Shannon-Weaver Genera Diversity
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	
Jun 2004	4,925,542	3	0.83	0	-----	0	-----	1	0.09	2	0.08	0	-----	0	-----	0.76
Jul 2004	832,108	0	-----	0	-----	0	-----	2	0.97	2	0.03	0	-----	0	-----	0.79
Aug 2004	75,169,830	6	0.62	3	0.01	0	-----	2	0.16	2	<0.01	2	0.20	1	0.01	1.92
May 2005	1,277,161,733	12	0.97	6	0.02	0	-----	2	0.01	4	<0.01	0	-----	0	-----	1.60
Jun 2005	12,054,751	4	0.41	4	0.19	0	-----	1	0.30	3	0.10	0	-----	0	-----	1.84
Jul 2005	103,882,588	6	0.91	2	<0.01	1	0.06	1	<0.01	3	0.02	0	-----	0	-----	1.43
Aug 2005	131,927,592	5	0.77	4	0.07	1	<0.01	2	0.09	0	-----	1	0.04	1	0.04	1.57
Sep 2005	20,963,108	3	0.15	1	0.01	0	-----	1	0.18	7	0.65	0	-----	0	-----	1.54
May 2006	1,511,202,710	6	1.00	2	<0.01	0	-----	1	<0.01	0	-----	0	-----	0	-----	0.73
Jun 2006	217,211,152	7	0.80	6	0.09	1	0.09	1	0.02	1	<0.01	0	-----	0	-----	1.44
Jul 2006	39,547,409	7	0.88	5	0.08	0	-----	1	0.02	3	0.02	0	-----	1	<0.01	1.44
Aug 2006	250,444,849	5	0.74	7	0.11	2	0.09	1	0.01	1	<0.01	1	0.03	1	0.03	1.57
Sep 2006	391,168,130	6	0.81	11	0.11	0	-----	1	0.02	3	0.01	1	0.03	1	0.01	1.88
May 2007	1,128,309,549	5	0.95	1	0.01	1	<0.01	1	0.02	0	-----	2	0.02	0	-----	1.10
Jun 2007	249,294,812	3	0.38	4	0.41	1	<0.01	1	0.21	0	-----	0	-----	0	-----	1.25
Jul 2007	101,717,269	8	0.61	8	0.15	0	-----	1	0.10	1	0.04	1	0.10	0	-----	1.83
Aug 2007	312,786,957	8	0.39	8	0.03	2	0.01	2	0.03	3	<0.01	1	0.54	1	<0.01	1.41
Sep 2007	228,330,946	7	0.70	11	0.13	0	-----	1	0.06	4	0.03	1	0.04	1	0.04	2.14
May 2008	784,108,007	10	1.00	3	<0.01	1	<0.01	1	<0.01	0	-----	0	-----	0	-----	1.14
Jun 2008	1,096,885,699	6	0.97	4	<0.01	2	0.01	1	0.02	1	<0.01	0	-----	0	-----	1.04
Jul 2008	7,177	3	0.06	0	-----	0	-----	1	0.94	1	<0.01	0	-----	0	-----	0.27
Aug 2008	13,678,405	2	0.02	5	0.50	0	-----	1	0.35	1	<0.01	1	0.13	0	-----	1.73
Sep 2008	376,464,061	6	0.80	13	0.05	0	-----	2	0.10	4	0.01	1	0.01	3	0.03	1.63
Mean*	**362,090,191**	**5.6**	**0.67**	**4.7**	**0.10**	**0.5**	**0.03**	**1.3**	**0.16**	**2.0**	**0.06**	**0.5**	**0.11**	**0.4**	**0.02**	**1.39**

* Mean percent composition represents the mean when taxa of that division are present.

Plate 273. Total biovolume, number of genera present, and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected in Fort Randall Reservoir at site FTRLK0911DW during the 3-year period 2006 through 2008.

Date	Total Sample Biovolume (um^3)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta		Shannon-Weaver Genera Diversity
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	
Jun 2006	69,931,419	5	0.44	7	0.36	2	0.08	1	0.04	1	0.06	1	0.03	0	-----	2.17
Jul 2006	98,641,374	2	0.34	5	0.13	0	-----	1	0.11	3	0.16	1	0.27	0	-----	1.86
Aug 2006	133,306,055	5	0.11	12	0.44	1	0.01	1	0.14	4	0.14	1	0.15	1	0.02	2.71
Sep 2006	83,623,877	10	0.32	15	0.43	0	-----	1	0.10	6	0.02	1	0.12	0	-----	2.59
Jun 2007	1,697,405,287	6	0.89	8	0.06	2	0.01	1	0.03	0	-----	1	0.01	0	-----	1.03
Jul 2007	529,054,652	6	0.04	7	0.02	1	0.01	1	0.02	3	0.88	1	0.04	0	----	0.73
Aug 2007	423,785,980	6	0 93	9	0.02	3	<0.01	2	0.01	3	<0.01	1	0.05	0	-----	1.09
Sep 2007	1,013,742,743	8	0.95	12	0.02	1	<0.01	2	<0.01	5	0.01	1	0.01	1	0.01	1.21
Jun 2008	644,247,513	8	0 95	11	0.01	1	0.01	1	0.02	0	-----	0	-----	0	-----	1.07
Jul 2008	295,300	4	0.87	6	0.02	1	<0.01	1	0.07	2	<0.01	1	0.04	0	-----	1.07
Aug 2008	131,718,414	6	0.62	6	0.01	0	-----	1	0.05	3	0.32	1	0.01	0	-----	1.41
Sep 2008	425,420,567	5	0.85	9	0.03	1	<0.01	2	0.07	6	0.02	2	0.02	1	<0.01	1.38
Mean*	**437,597,765**	**5.92**	**0.61**	**8.92**	**0.13**	**1.08**	**0.01**	**1.25**	**0.06**	**3.00**	**0.16**	**1.00**	**0.07**	**0.25**	**0.01**	**1.53**

* Mean percent composition represents the mean when taxa of that division are present.

Plate 274. Total biovolume, number of genera present, and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected in Fort Randall Reservoir at site FTRLK0940DW during the 3-year period 2006 through 2008.

Date	Total Sample Biovolume (um^3)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta		Shannon-Weaver Genera Diversity
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	
Jun 2006	518,893,912	11	0 92	9	0.05	0	-----	0	-----	1	0.03	0	-----	0	-----	1.06
Jul 2006	119,552,113	11	0.81	8	0.07	1	<0.01	0	-----	1	0.06	1	0.05	1	0.01	1.77
Aug 2006	320,031,467	12	0.72	15	0.12	1	0.01	1	<0.01	5	0.14	1	0.01	1	<0.01	2.86
Sep 2006	365,369,612	18	0.83	10	0.11	1	0.03	0	-----	0	-----	1	0.04	0	-----	2.77
Jun 2007	7,768,787,921	8	0 91	10	0.03	2	0.02	1	0.01	5	0.03	1	0.01	0	-----	0.80
Jul 2007	583,012,381	12	0.50	8	0.01	0	-----	1	0.01	3	0.47	1	0.01	0	-----	1.69
Aug 2007	210,296,968	10	0.48	11	0.22	1	<0.01	2	0.06	3	0.12	2	0.11	0	-----	2.72
Jun 2008	145,687,021	10	0.84	9	0.05	2	0.04	1	0.06	1	<0.01	0	-----	0	-----	1.40
Jul 2008	745,624	5	0.86	6	0.07	1	<0.01	1	0.01	6	0.06	2	<0.01	2	<0.01	1.28
Aug 2008	217,934,376	11	0.95	4	<0.01	0	-----	1	<0.01	2	<0.01	1	0.01	3	0.01	1.27
Mean*	**1,025,031,140**	**10.80**	**0.78**	**9.00**	**0.07**	**0.90**	**0.01**	**0.80**	**0.02**	**2.70**	**0.10**	**1.00**	**0.03**	**0.70**	**0.01**	**1.76**

* Mean percent composition represents the mean when taxa of that division are present.

Plate 275. Total biovolume, number of genera present, and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected in Fort Randall Reservoir at site FTRLK0968DW during the 3-year period 2006 through 2008.

Date	Total Sample Biovolume (um^3)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta		Shannon-Weaver Genera Diversity
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	
Jun 2006	3,042,159,471	9	0.94	9	0.04	1	<0.01	1	<0.01	2	0.01	1	<0.01	0	-----	0.44
Jul 2006	235,103,339	7	0.24	6	0.72	1	<0.01	1	0.01	1	0.03	0	-----	1	<0.01	1.37
Aug 2006	842,613,801	19	0 91	14	0.04	2	<0.01	1	<0.01	6	0.03	1	0.01	1	<0.01	1.80
Sep 2006	270,757,940	17	0.80	11	0.14	1	0.01	1	<0.01	1	<0.01	1	0.04	2	0.01	2.42
Jun 2007	1,073,452,712	5	0.71	11	0.14	2	0.01	1	0.03	1	<0.01	1	0.11	0	-----	1.49
Jul 2007	405,005,185	14	0.42	6	0.02	1	<0.01	1	0.05	1	0.37	1	0.12	0	0.01	2.02
Aug 2007	162,100,006	11	0.55	6	0.03	2	0.02	1	0.01	3	<0.01	1	0.31	2	0.08	2.30
Sep 2007	121,850,078	8	0.73	6	0.03	1	<0.01	1	0.05	5	0.18	0	-----	0	-----	2.15
Jun 2008	1,161,968,310	8	0.96	9	0.01	2	<0.01	1	0.03	1	<0.01	0	-----	0	-----	0.93
Jul 2008	238,272	4	0.86	2	0.01	0	-----	1	0.01	6	0.12	0	-----	0	-----	0.63
Aug 2008	133,462,205	10	0.94	3	0.01	0	-----	1	0.03	3	<0.01	1	0.01	0	-----	1.30
Sep 2008	103,962,738	10	0.86	2	0.02	1	<0.01	2	0.08	1	<0.01	0	-----	3	0.04	1.51
Mean*	**629,389,505**	**10.17**	**0.74**	**7.08**	**0.10**	**1.17**	**<0.01**	**1.08**	**0.03**	**2.58**	**0.06**	**0.58**	**0.09**	**0.75**	**0.02**	**1.53**

* Mean percent composition represents the mean when taxa of that division are present.

Plate 276. Dominant taxa present in phytoplankton grab samples collected at the near-dam monitoring site (site FTRLK0880A) at Fort Randall Reservoir during the 5-year period 2004 through 2008.

Date	Division	Dominant Taxa*	Percent of Total Biovolume
June 2004	Bacillariophyta	*Fragilaria crotonensis*	0.81
July 2004	Cryptophyta	*Rhodomonas minuta*	0.60
	Cryptophyta	*Cryptomonas spp.*	0.37
August 2004	Bacillariophyta	*Tabellaria spp.*	0.23
	Pyrrophyta	*Ceratium hirundinella*	0.20
	Bacillariophyta	*Fragilaria crotonensis*	0.19
	Cryptophyta	*Cryptomonas spp.*	0.14
	Bacillariophyta	*Asterionella formossa*	0.14
May 2005	Bacillariophyta	*Fragilaria crotonensis*	0.47
	Bacillariophyta	*Asterionella formossa*	0.20
	Bacillariophyta	*Stephanodiscus spp.*	0.12
	Bacillariophyta	*Melosira varians*	0.11
June 2005	Cryptophyta	*Rhodomonas minuta*	0.30
	Bacillariophyta	*Stephanodiscus spp.*	0.22
	Bacillariophyta	*Cyclotella spp.*	0.17
July 2005	Bacillariophyta	*Fragilaria crotonensis*	0.45
	Bacillariophyta	*Synedra spp.*	0.33
August 2005	Bacillariophyta	*Cyclotella spp.*	0.48
	Bacillariophyta	*Synedra spp.*	0.20
September 2005	Cyanobacteria	*Planktolyngbya limnetica*	0.52
	Cyanobacteria	*Oscillatoria spp.*	0.12
	Cryptophyta	*Rhodomonas minuta*	0.11
May 2006	Bacillariophyta	*Fragilaria crotonensis*	0.51
	Bacillariophyta	*Asterionella formossa*	0.44
June 2006	Bacillariophyta	*Fragilaria crotonensis*	0.41
	Bacillariophyta	*Asterionella formossa*	0.18
July 2006	Bacillariophyta	*Asterionella formossa*	0.45
	Bacillariophyta	*Fragilaria crotonensis*	0.35
August 2006	Bacillariophyta	*Fragilaria crotonensis*	0.56
	Bacillariophyta	*Aulacoseira granulata*	0.16
September 2006	Bacillariophyta	*Aulacoseira granulata*	0.41
	Bacillariophyta	*Stephanodiscus niagarea*	0.20
	Bacillariophyta	*Fragilaria crotonensis*	0.10
May 2007	Bacillariophyta	*Fragilaria spp.*	0.69
	Bacillariophyta	*Aulacoseira spp.*	0.12
	Bacillariophyta	*Tabellaria flocculosa.*	0.10
June 2007	Chlorophyta	*Pyramichlamys spp.*	0.39
	Bacillariophyta	*Fragilaria spp.*	0.35
	Cryptophyta	*Rhodomonas spp.*	0.21
July 2007	Bacillariophyta	*Fragilaria spp.*	0.48
	Pyrrophyta	*Ceratium hirundinella*	0.10
August 2007	Pyrrophyta	*Ceratium hirundinella*	0.54
	Bacillariophyta	*Fragilaria capucina var. gracilis*	0.25
	Bacillariophyta	*Aulacoseira spp.*	0.11
September 2007	Bacillariophyta	*Stephanodiscus spp.*	0.31
	Bacillariophyta	*Aulacoseira spp.*	0.21
	Bacillariophyta	*Fragilaria spp.*	0.15

Plate 276. (Continued).

Date	Division	Dominant Taxa*	Percent of Total Biovolume
May 2008	Bacillariophyta	*Fragilaria crotonensis*	0.61
	Bacillariophyta	*Tabellaria flocculosa*	0.19
	Bacillariophyta	*Aulacoseira granulata*	0.12
June 2008	Bacillariophyta	*Fragilaria crotonensis*	0.58
	Bacillariophyta	*Asterionella formossa*	0.28
	Bacillariophyta	*Tabellaria flocculosa*	0.11
July 2008	Cryptophyta	*Rhodomonas minuta var. nannoplanctica*	0.60
	Cryptophyta	*Rhodomonas lacustris*	0.33
August 2008	Cryptophyta	*Rhodomonas minuta var. nannoplanctica*	0.32
	Chlorophyta	*Chlamydomonas sp.*	0.22
	Pyrrophyta	*Ceratium hirundinella*	0.13
	Chlorophyta	*Staurastrum sp.*	0.11
September 2008	Bacillariophyta	*Aulacoseira granulata*	0.41
	Bacillariophyta	*Fragilaria crotonensis*	0.35

* Dominant taxa are genera or species (depending on identification level) that comprised more than 10% of the total sample biovolume.

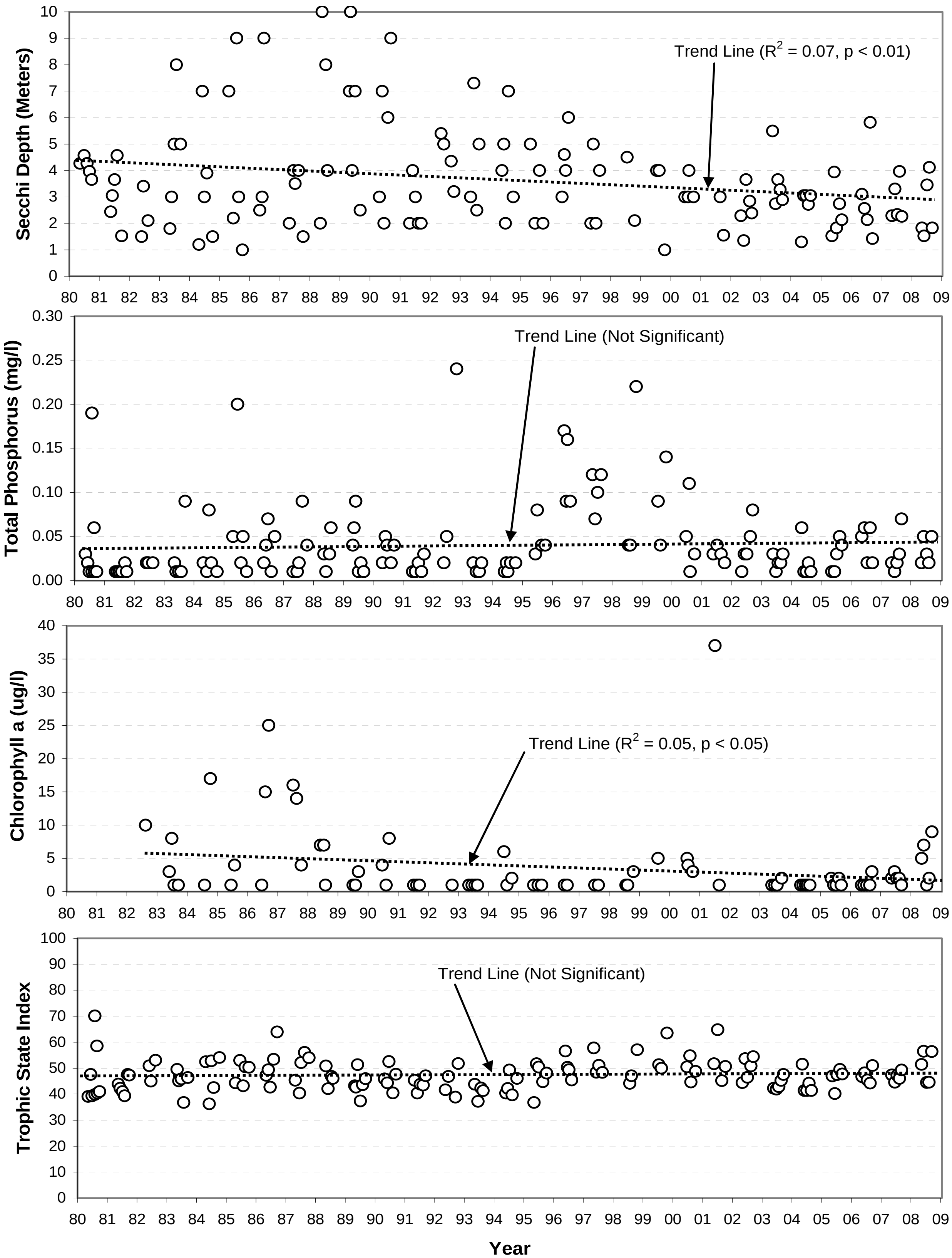


Plate 277. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and Trophic State Index (TSI) monitored in Fort Randall Reservoir at the near-dam, ambient site (i.e., site FTRLK0880A) over the 29-year period of 1980 through 2008.

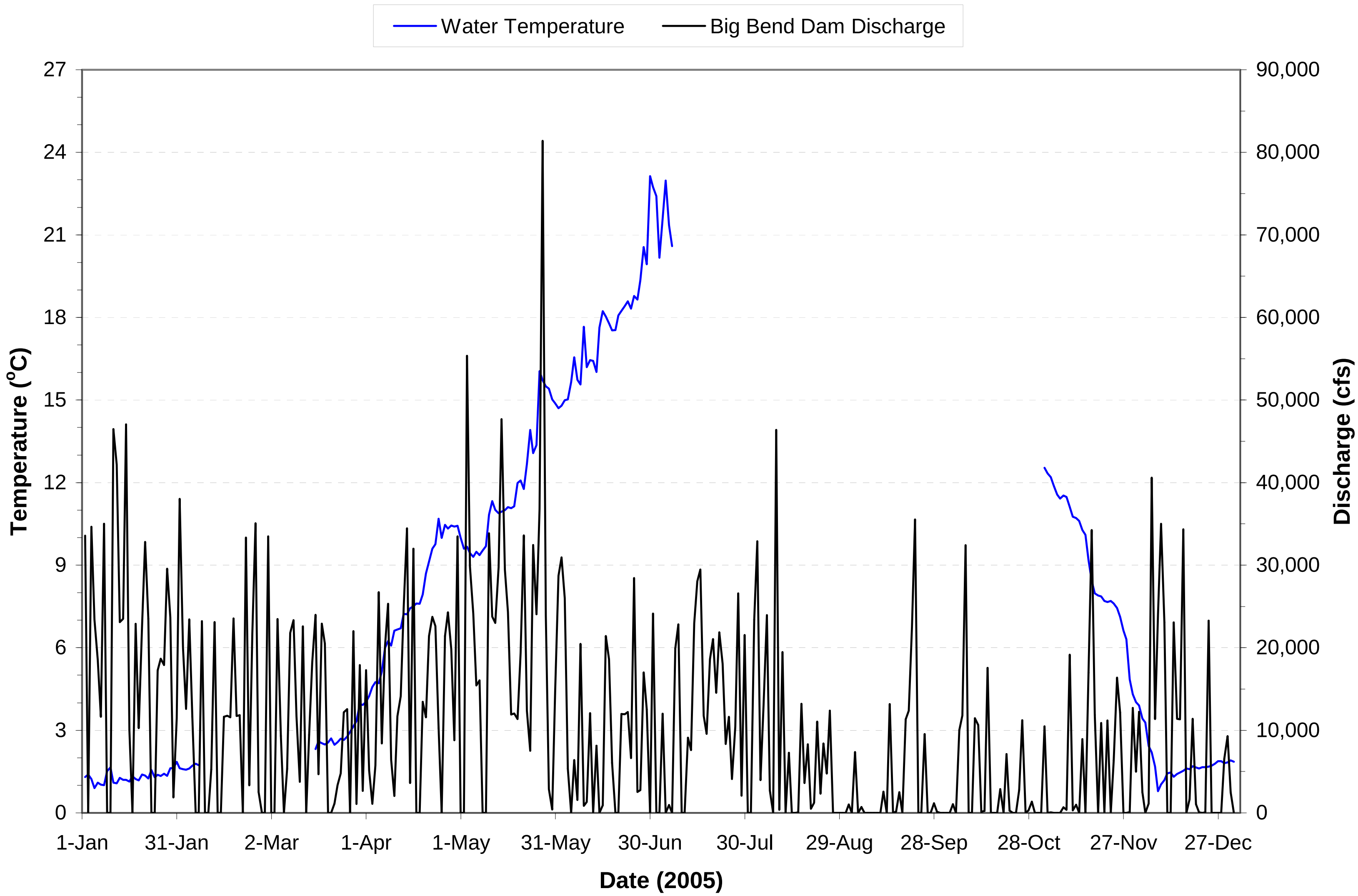


Plate 278. Mean daily water temperature and discharge of the Missouri River at Big Bend Dam (i.e., site BBDPP1) for 2005. Mean daily temperatures and discharges based on hourly measurements recorded on discharge through Big Bend Dam.
(Note: Gaps in temperature plots are periods when monitoring equipment was not operational.)

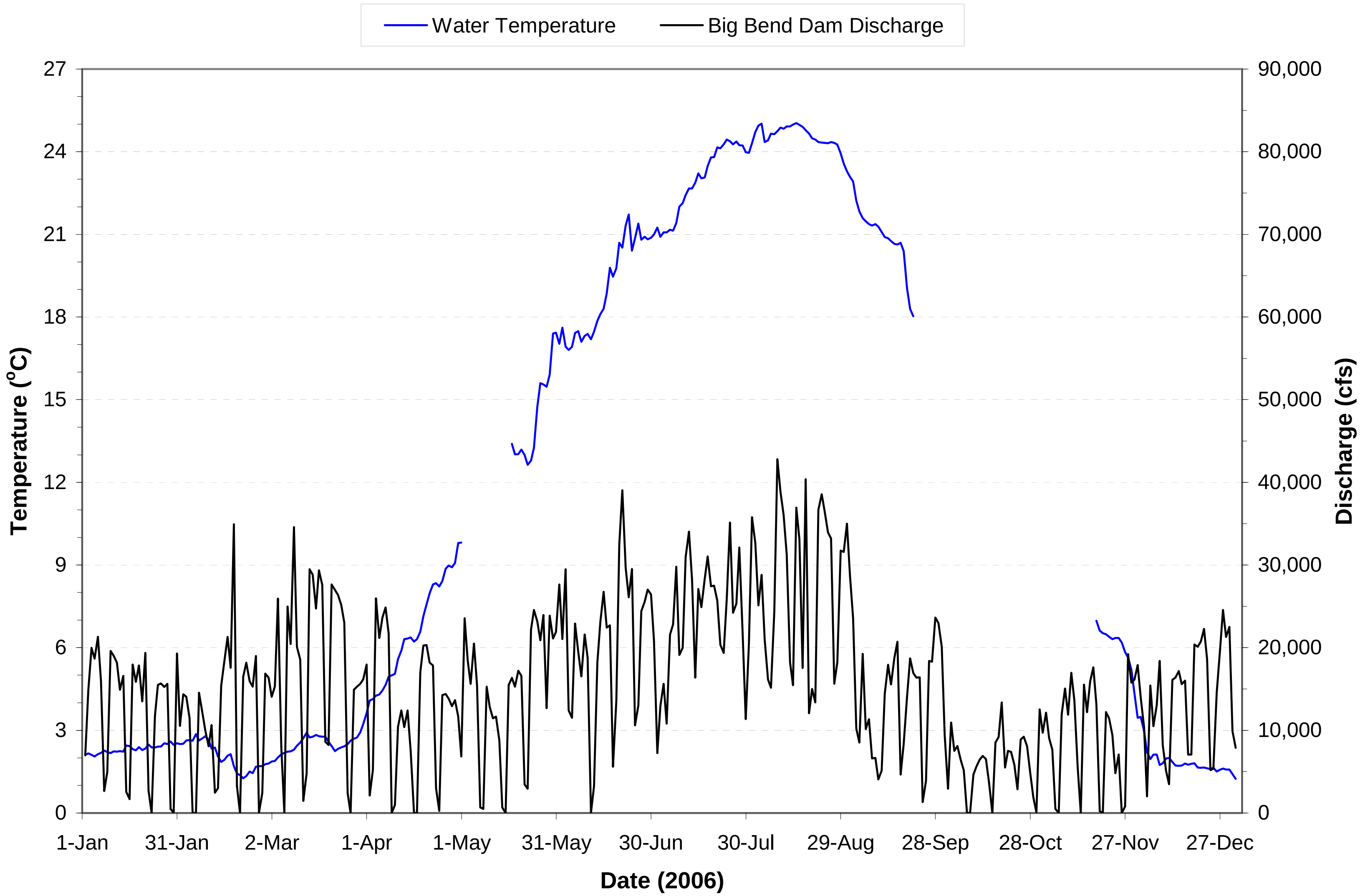


Plate 279. Mean daily water temperature and discharge of the Missouri River at Big Bend Dam (i.e., site BBDPP1) for 2006. Mean daily temperatures and discharges based on hourly measurements recorded on discharge through Big Bend Dam.
(Note: Gaps in temperature plots are periods when monitoring equipment was not operational.)

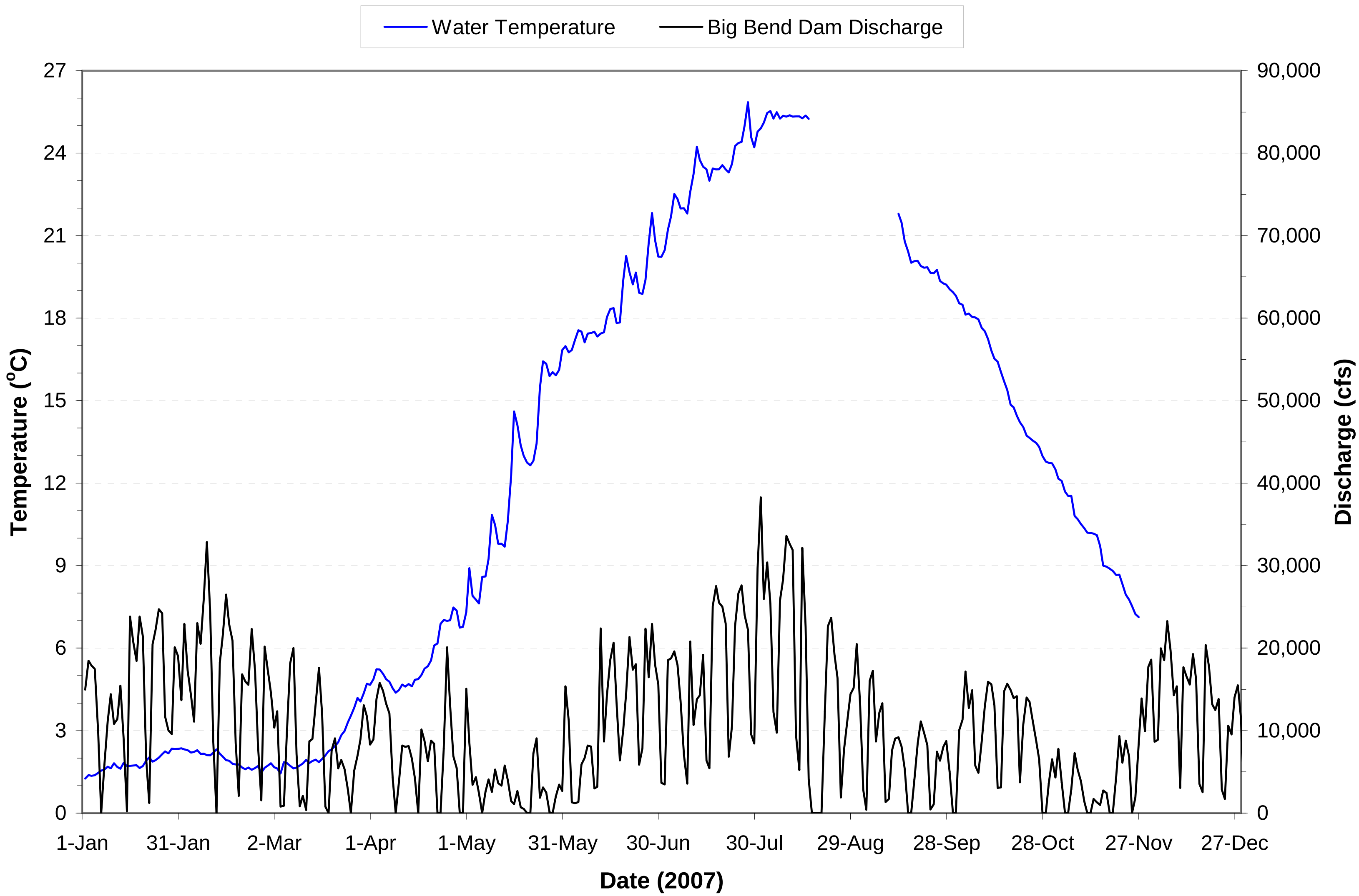


Plate 280. Mean daily water temperature and discharge of the Missouri River at Big Bend Dam (i.e., site BBDPP1) for 2007. Mean daily temperatures and discharges based on hourly measurements recorded on discharge through Big Bend Dam.
(Note: Gaps in temperature plots are periods when monitoring equipment was not operational.)

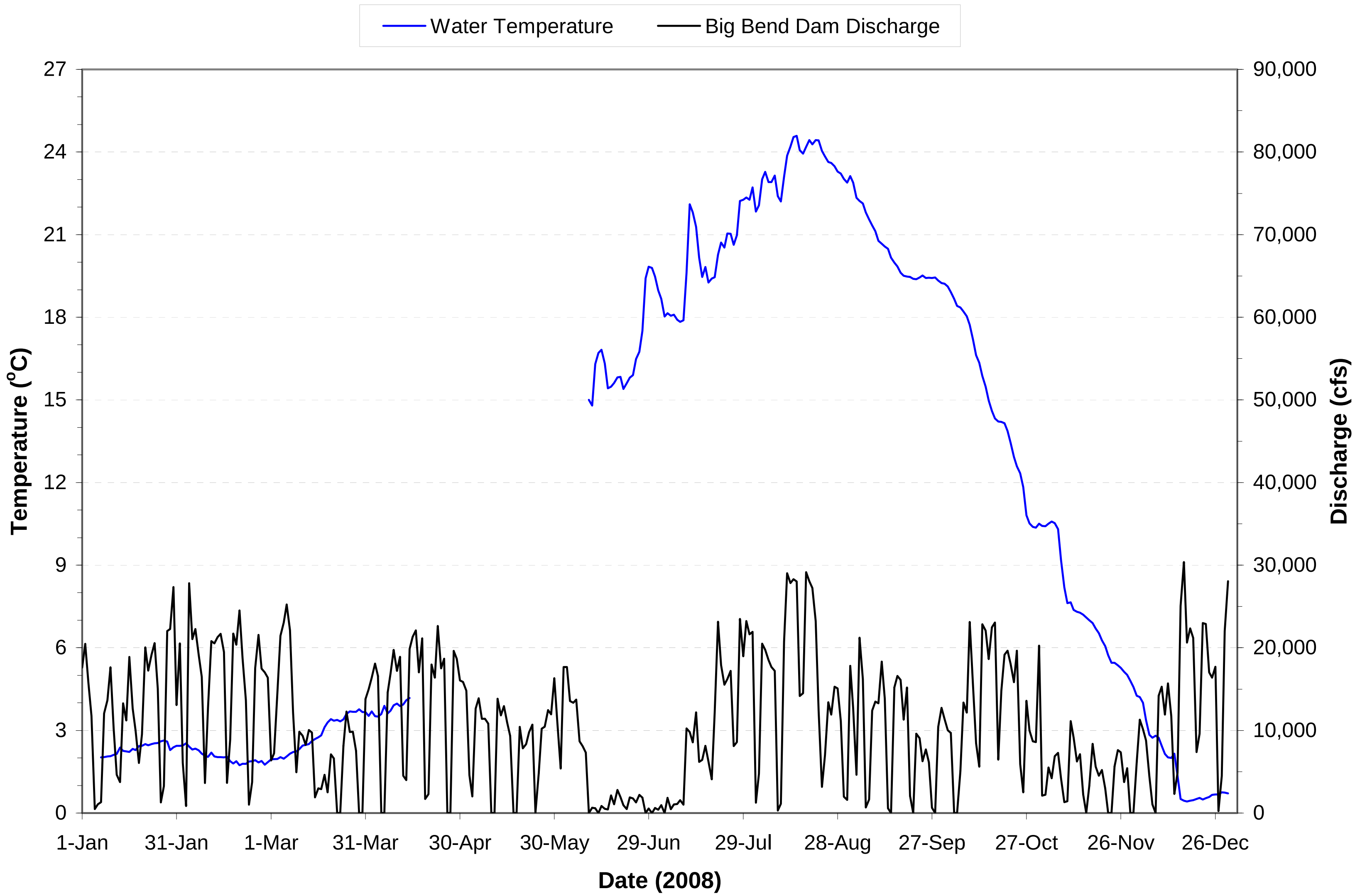


Plate 281. Mean daily water temperature and discharge of the Missouri River at Big Bend Dam (i.e., site BBDPP1) for 20087. Mean daily temperatures and discharges based on hourly measurements recorded on discharge through Big Bend Dam.
(Note: Gaps in temperature plots are periods when monitoring equipment was not operational.)

Plate 282. Summary of water quality conditions monitored on water discharged through Fort Randall Dam (i.e., site FTRPP1) during the 5-year period of 2004 through 2008.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit[A]	No. of Obs.	Mean[B]	Median	Min.	Max.	State WQS Criteria[C]	No. of WQS Exceedences	Percent WQS Exceedence
Dam Discharge (cfs)	1	48	20,725	19,943	0	41,200	-----	-----	-----
Water Temperature (C)	0.1	46	12.8	13.5	0.6	25.4	27[1,4]	0	0%
Dissolved Oxygen (mg/l)	0.1	46	9.6	9.7	6.5	13.4	≥ 5[1,5]	0	0%
Dissolved Oxygen (% Sat.)	0.1	46	91.7	93.6	68.9	103.9	-----	-----	-----
pH (S.U.)	0.1	40	8.3	8.3	7.2	8.7	6 5[1,2,5], 9.0[1,2,4], 9.5[3,4]	0	0%
Specific Conductance (umho/cm)	1	46	692	711	562	776	-----	-----	-----
Oxidation-Reduction Potential	1	27	370	363	273	458	-----	-----	-----
Turbidity (NTU)	1	22	4	3	n.d.	17	-----	-----	-----
Alkalinity, Total (mg/l)	7	48	167	170	130	205	-----	-----	-----
Ammonia, Total (mg/l)	0.02	48	-----	0.07	n.d.	0.42	3.1 [1,4,7], 1.4 [1,6,7]	0	0%
Carbon, Total Organic (mg/l)	0.05	46	3.2	3.1	2.5	5.0	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	31	11	11	n.d.	22	-----	-----	-----
Chloride (mg/l)	1	29	11	12	9	14	175[1,4], 100[1,6], 438[2,4], 250[2,6]	0	0%
Dissolved Solids, Total (mg/l)	5	48	461	472	314	568	1,750[2,4], 1,000[2,7], 3,500[3,4], 2,000[3,6]	0	0%
Hardness, Total (mg/l)	0.4	7	221	217	211	238	-----	-----	-----
Iron, Total (ug/l)	40	30	118	85	n.d.	1,121	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	48	0.5	0.3	n.d.	3.6	-----	-----	-----
Manganese, Total (ug/l)	2	30	19	16	n.d.	47	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	48	-----	n.d.	n.d.	0.10	10[2,4]	0	0%
Phosphorus, Dissolved (mg/l)	0.02	28	----	n.d.	n.d.	0.07	-----	-----	-----
Phosphorus, Total (mg/l)	0.02	48	-----	0.02	n.d.	0.25	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.02	46	-----	n.d.	n.d.	0.02	-----	-----	-----
Sulfate (mg/l)	1	48	203	204	117	232	875[2,4], 500[2,6]	0	0%
Suspended Solids, Total (mg/l)	4	48	-----	n.d.	n.d.	26	158[1,4], 90[1,6]	0	0%
Aluminum, Dissolved (ug/l)	25	3	-----	n.d.	n.d.	n.d.	-----	-----	-----
Antimony, Dissolved (ug/l)	0.5	4	-----	n.d.	n.d.	0.6	5.6[10]	0	0%
Arsenic, Dissolved (ug/l)	1	7	-----	n.d.	n.d.	2	340[8], 150[9], 0.018[10]	b.d.	b.d.
Barium, Dissolved (ug/l)	5	2	32	32	31	32	-----	0	0%
Beryllium, Dissolved (ug/l)	2	4	-----	n.d.	n.d.	n.d.	4[10]	0	0%
Cadmium, Dissolved (ug/l)	0.2	7	-----	n.d.	n.d.	n.d.	4.3[8], 0.42[9], 5[10]	0	0%
Chromium, Dissolved (ug/l)	10	7	-----	n.d.	n.d.	n.d.	1,074[8], 140[9]	0	0%
Copper, Dissolved (ug/l)	2	7	-----	2	n.d	5	28[8], 17[9], 1,300[10]	0	0%
Lead, Dissolved (ug/l)	0.5	7	-----	n.d.	n.d.	n.d.	148[8], 5.8[9]	0	0%
Mercury, Dissolved (ug/l)	0.02	8	-----	n.d.	n.d.	n.d.	1.7[8], 0.05[9]	0	0%
Mercury, Total (ug/l)	0.02	8	-----	n.d.	n.d.	n.d.	0.77[9]	0	0%
Nickel, Dissolved (ug/l)	10	7	-----	n.d.	n.d.	n.d.	902[8], 100[9], 610[10]	0	0%
Selenium, Total (ug/l)	1	6	-----	n.d.	n.d.	3	-----	0	0%
Silver, Dissolved (ug/l)	1	7	-----	n.d.	n.d.	n.d.	12[8]	0	0%
Thallium, Dissolved (ug/l)	0.5	4	-----	n.d.	n.d.	n.d.	0.24[10]	0	0%
Zinc, Dissolved (ug/l)	10	7	-----	n.d.	n.d.	10	226[8,9], 7,400[10]	0	0%
Pesticide Scan (ug/l)[D]	0.05	5	-----	n.d.	n.d.	n.d.	-----	-----	-----

n.d. = Not detected. b.d. = Criterion below detection limit.

(A) Detection limits given for the parameters Stream Flow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for the protection of warmwater permanent fish life propagation waters.
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of commerce and industry waters.
- (4) Daily maximum criterion (monitoring results directly comparable to criterion).
- (5) Daily minimum criterion (monitoring results directly comparable to criterion).
- (6) 30-day average criterion (monitoring results not directly comparable to criterion).
- (7) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (8) Acute (CMC) criterion for the protection of freshwater aquatic life.
- (9) Chronic (CCC) criterion for the protection of freshwater aquatic life.
- (10) Criterion for the protection of human health.

Note: Some of South Dakota's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

(D) The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, cycloate, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, isopropalin, metolachlor, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, phorate, profluralin, prometon, propachlor, propazine, simazine, terbufos, triallate, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

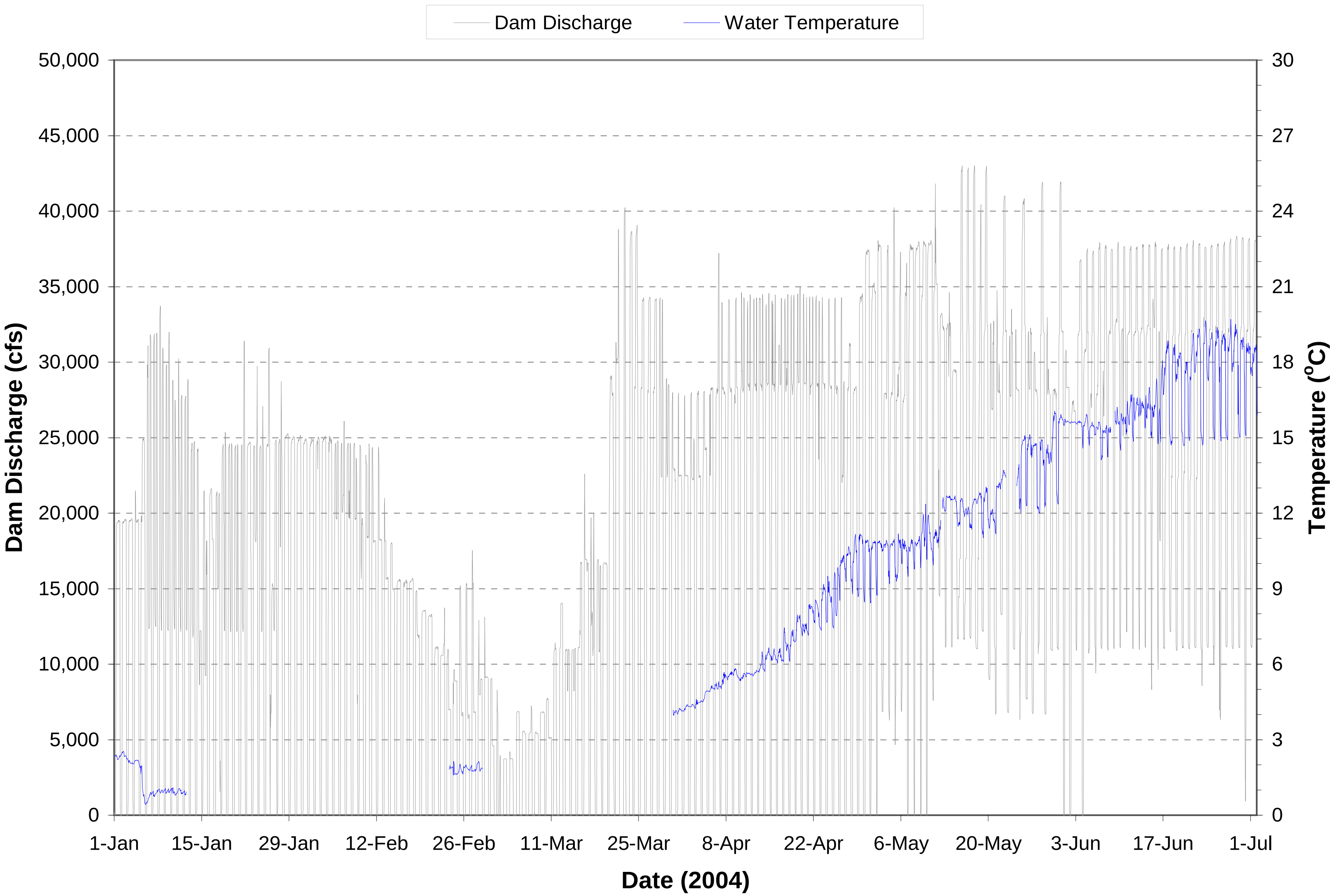


Plate 283. Hourly discharge and water temperature monitored at the Fort Randall powerplant on water discharged through the dam during the period January through June 2004.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

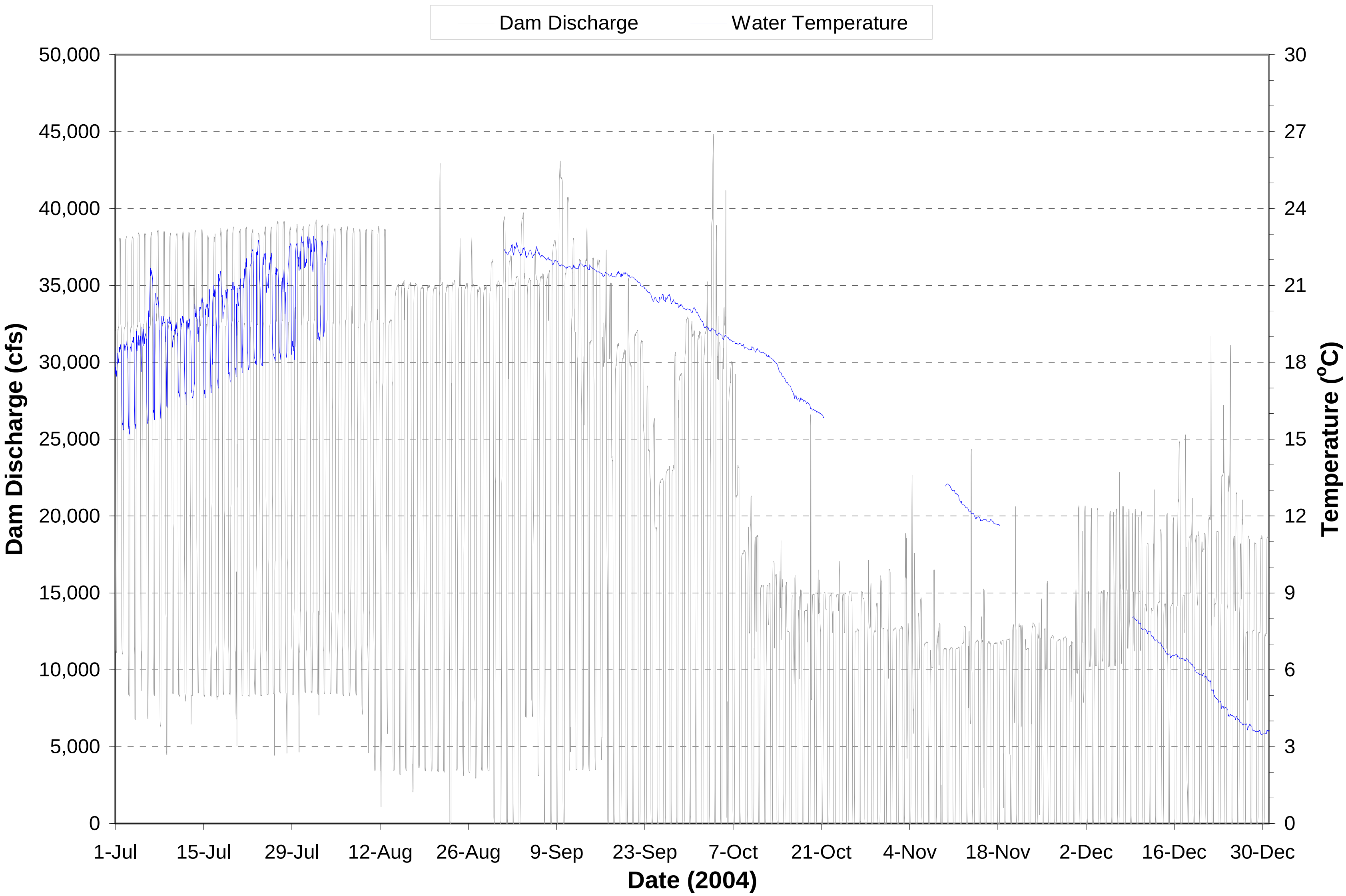


Plate 284. Hourly discharge and water temperature monitored at the Fort Randall powerplant on water discharged through the dam during the period July through December 2004.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

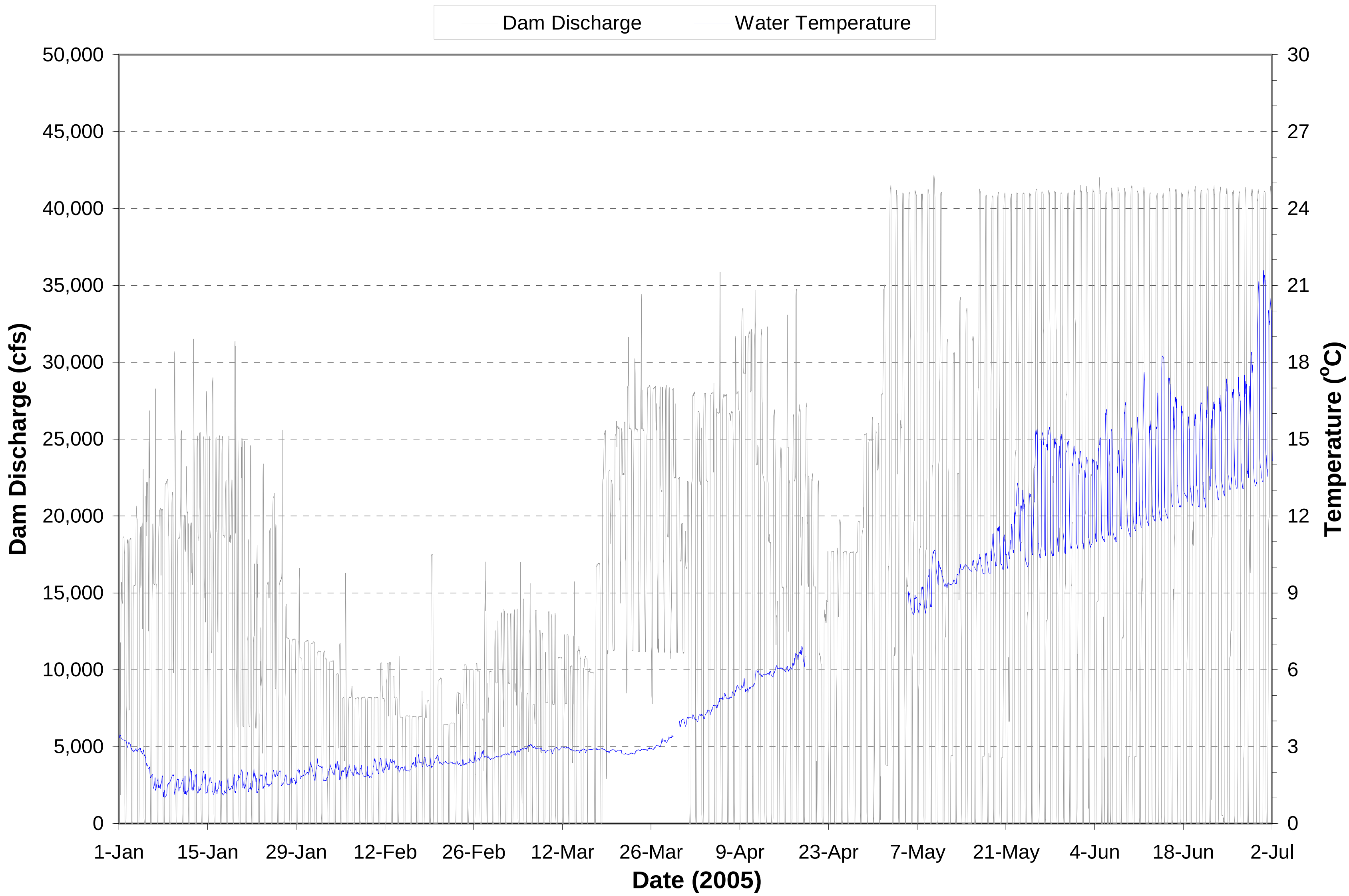


Plate 285. Hourly discharge and water temperature monitored at the Fort Randall powerplant on water discharged through the dam during the period January through June 2005.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

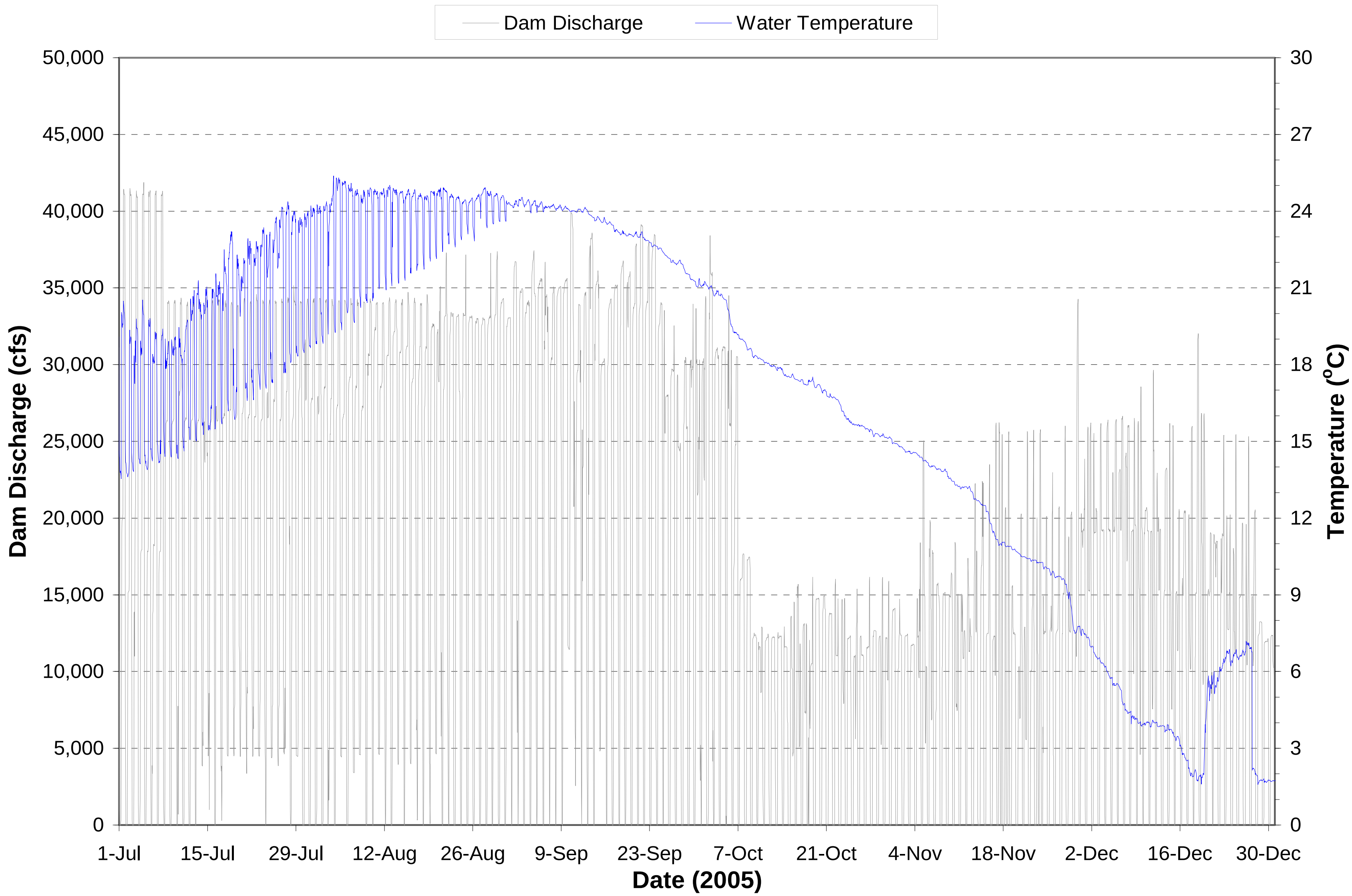


Plate 286. Hourly discharge and water temperature monitored at the Fort Randall powerplant on water discharged through the dam during the period July through December 2005.

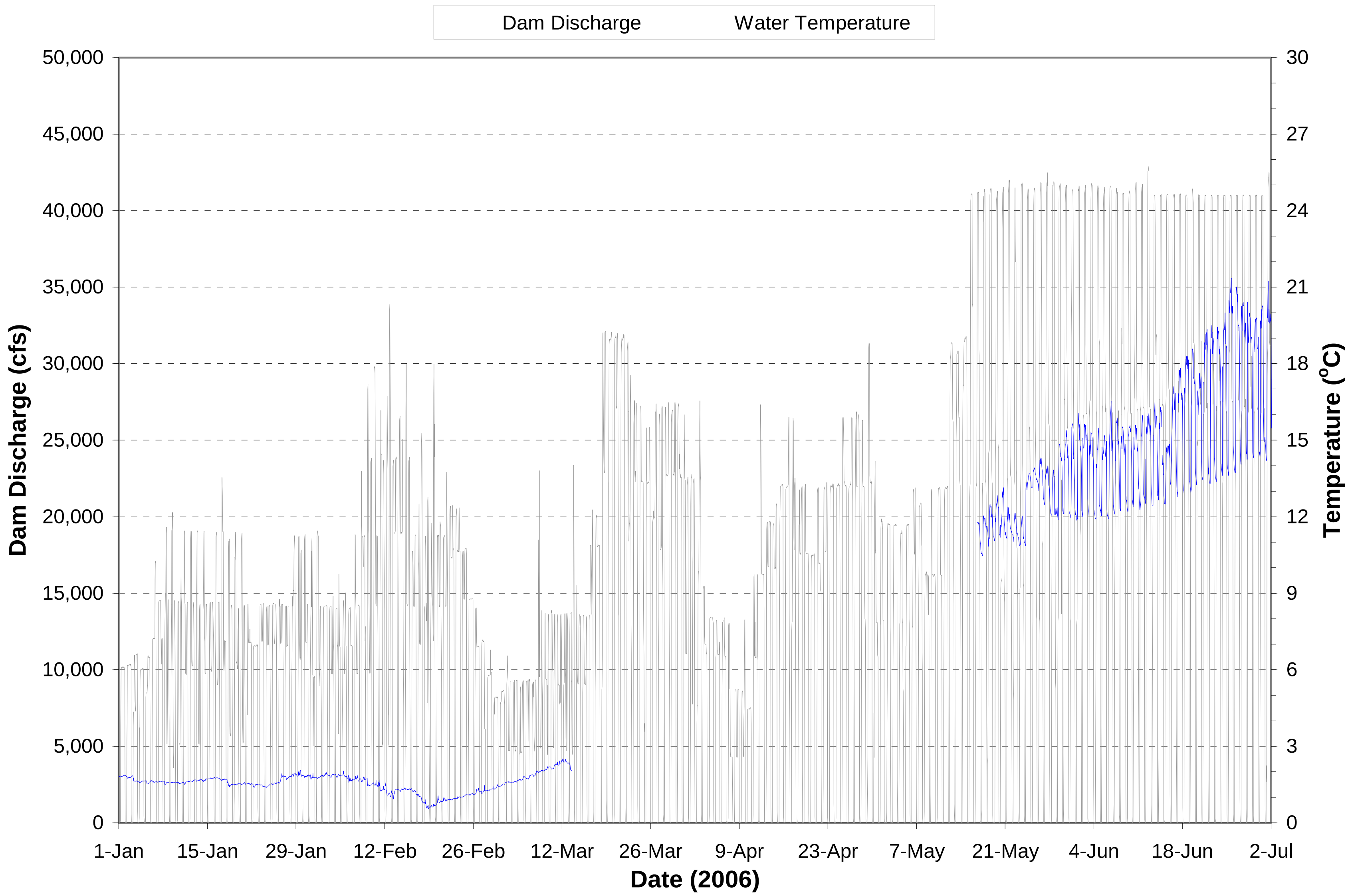


Plate 287. Hourly discharge and water temperature monitored at the Fort Randall powerplant on water discharged through the dam during the period January through June 2006.
(Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.)

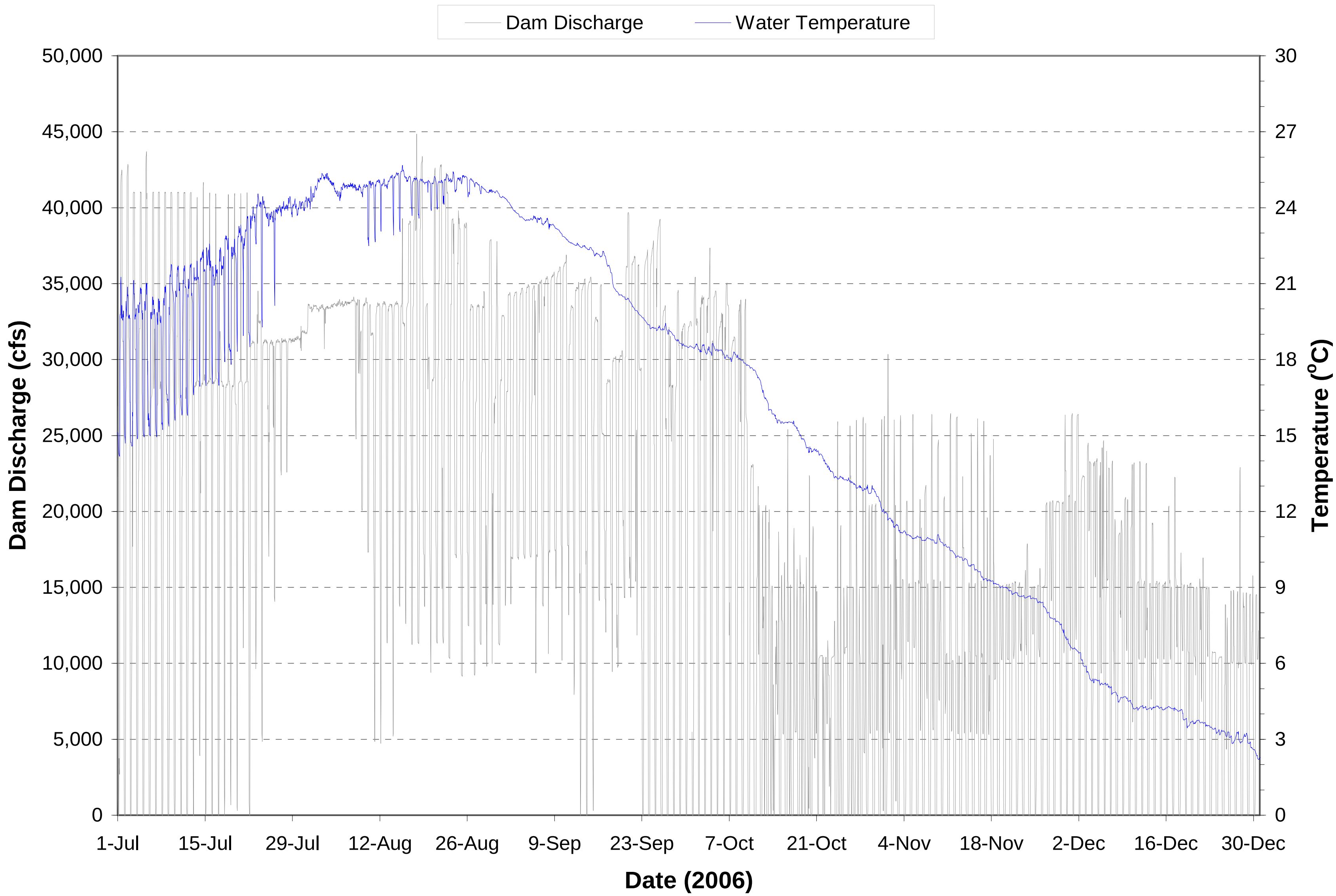


Plate 288. Hourly discharge and water temperature monitored at the Fort Randall powerplant on water discharged through the dam during the period July through December 2006.

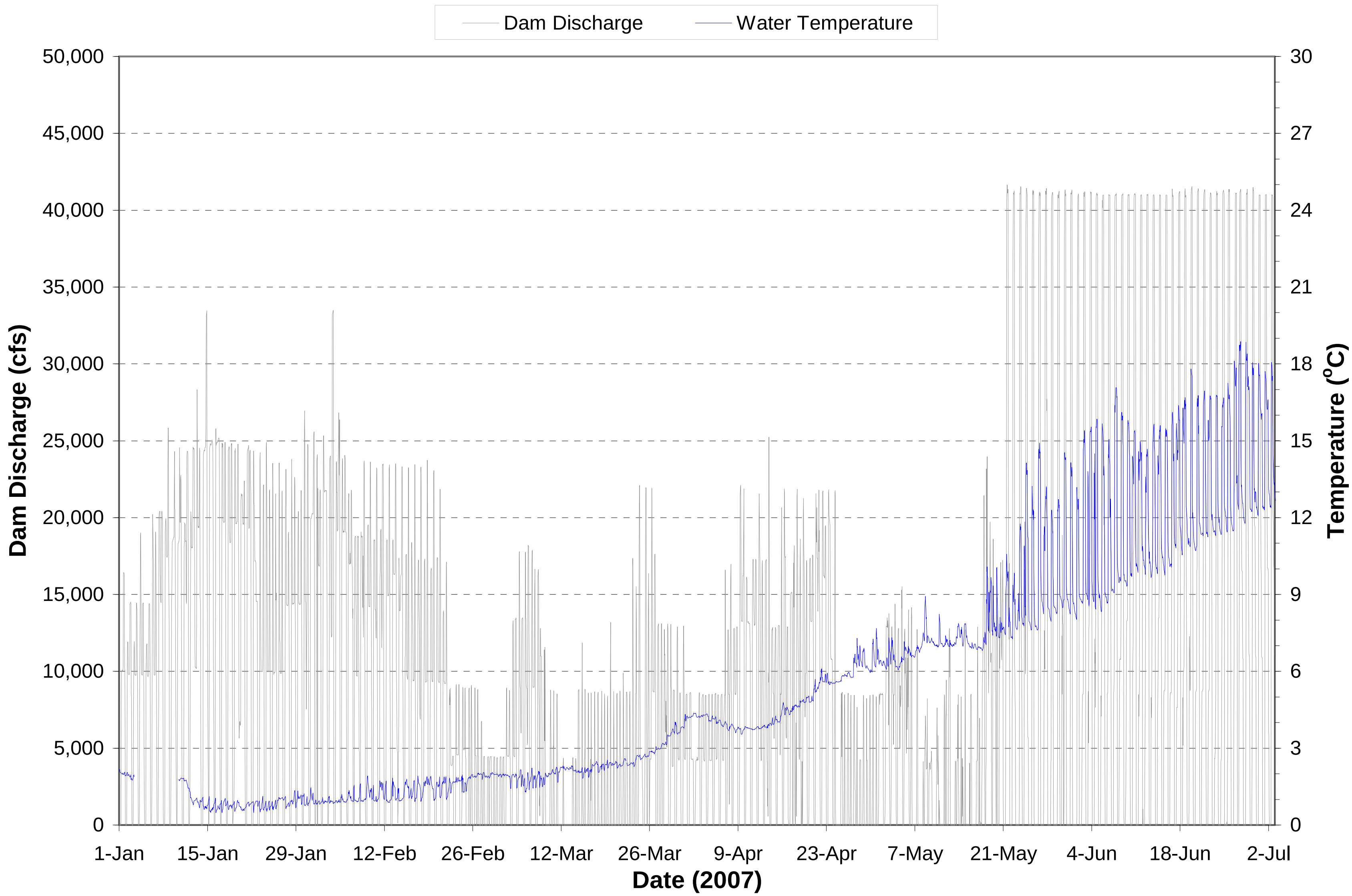


Plate 289. Hourly discharge and water temperature monitored at the Fort Randall powerplant on water discharged through the dam during the period January through June 2007.

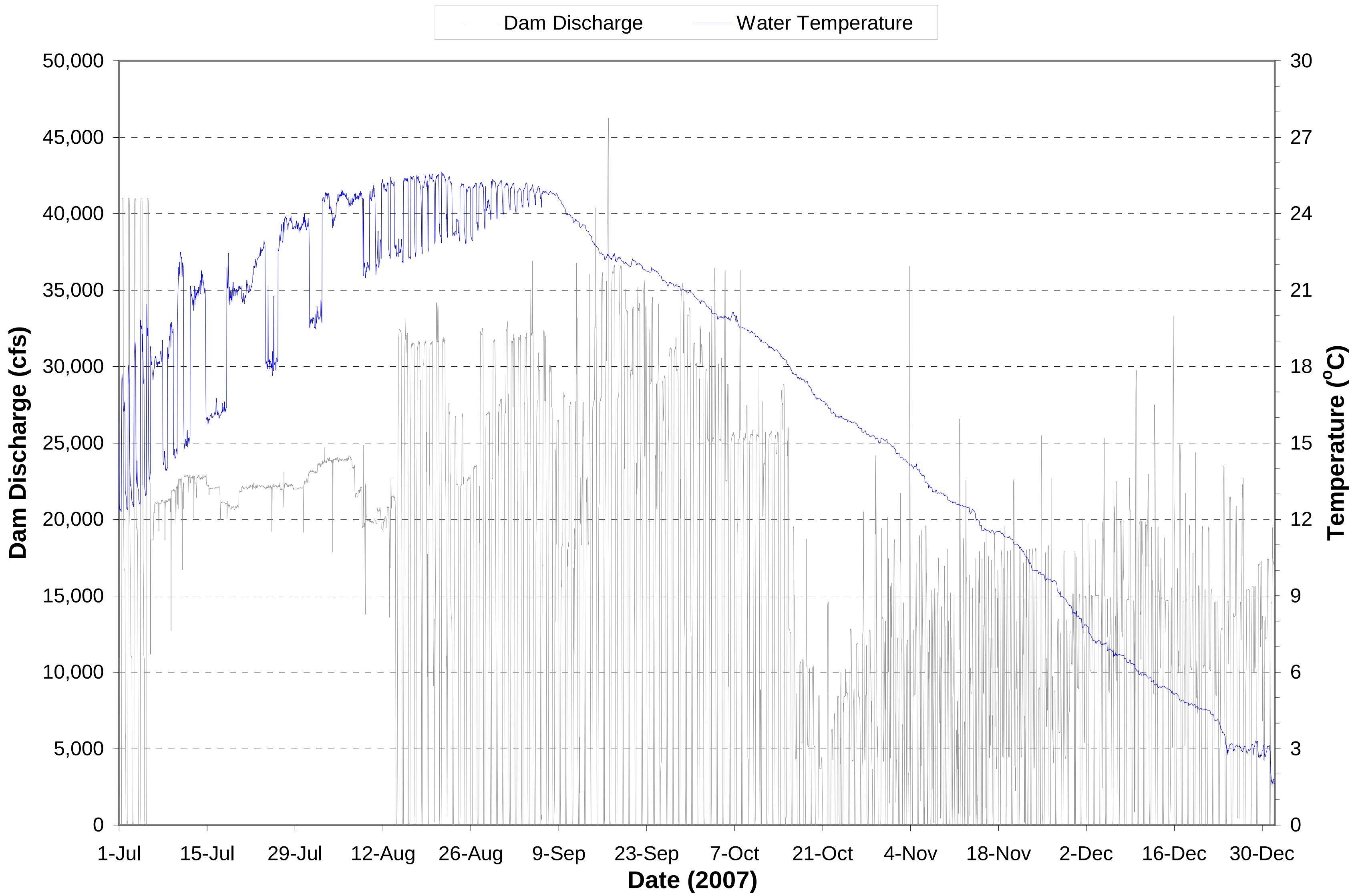


Plate 290. Hourly discharge and water temperature monitored at the Fort Randall powerplant on water discharged through the dam during the period July through December 2007.

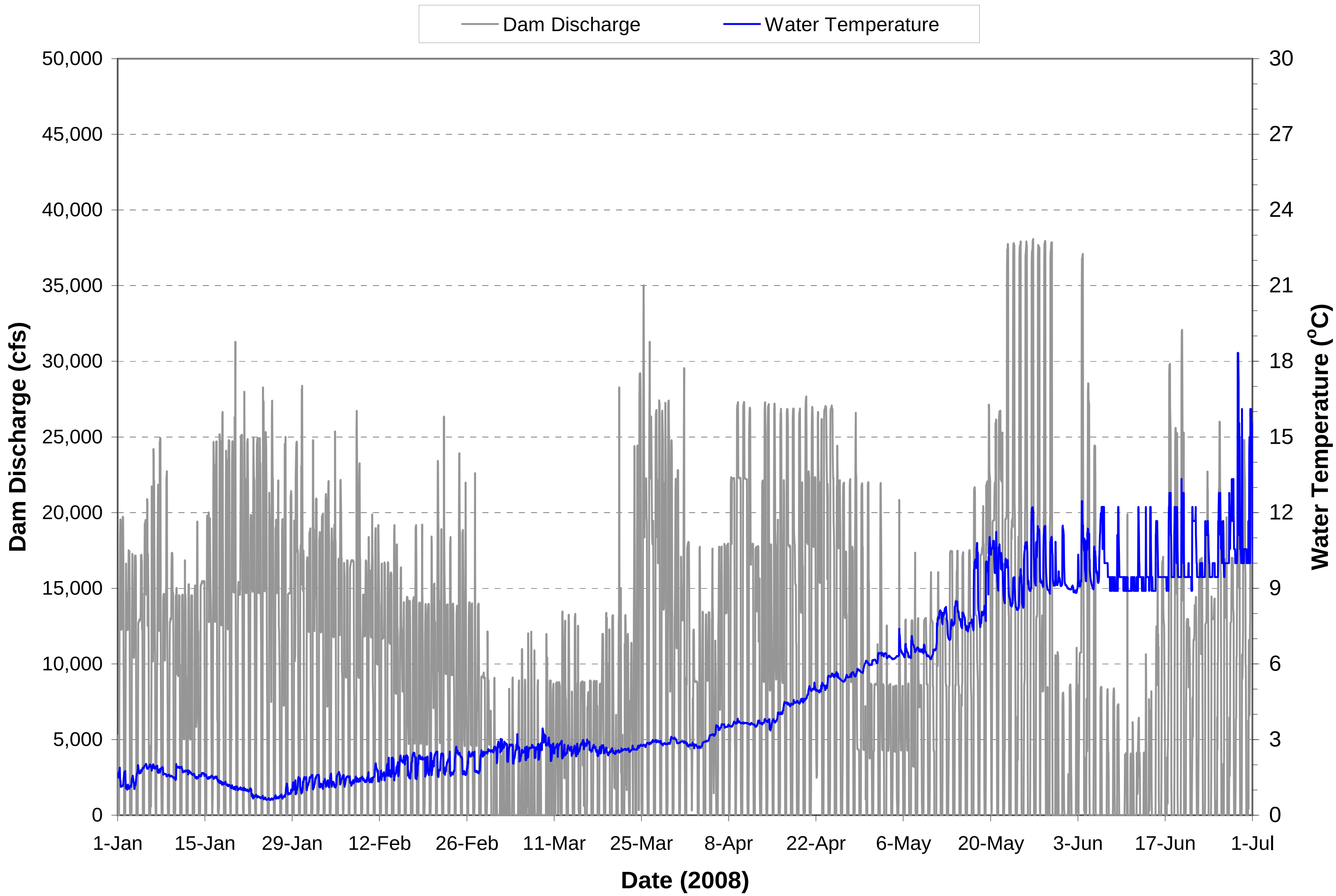


Plate 291. Hourly discharge and water temperature monitored at the Fort Randall powerplant on water discharged through the dam during the period January through June 2008.

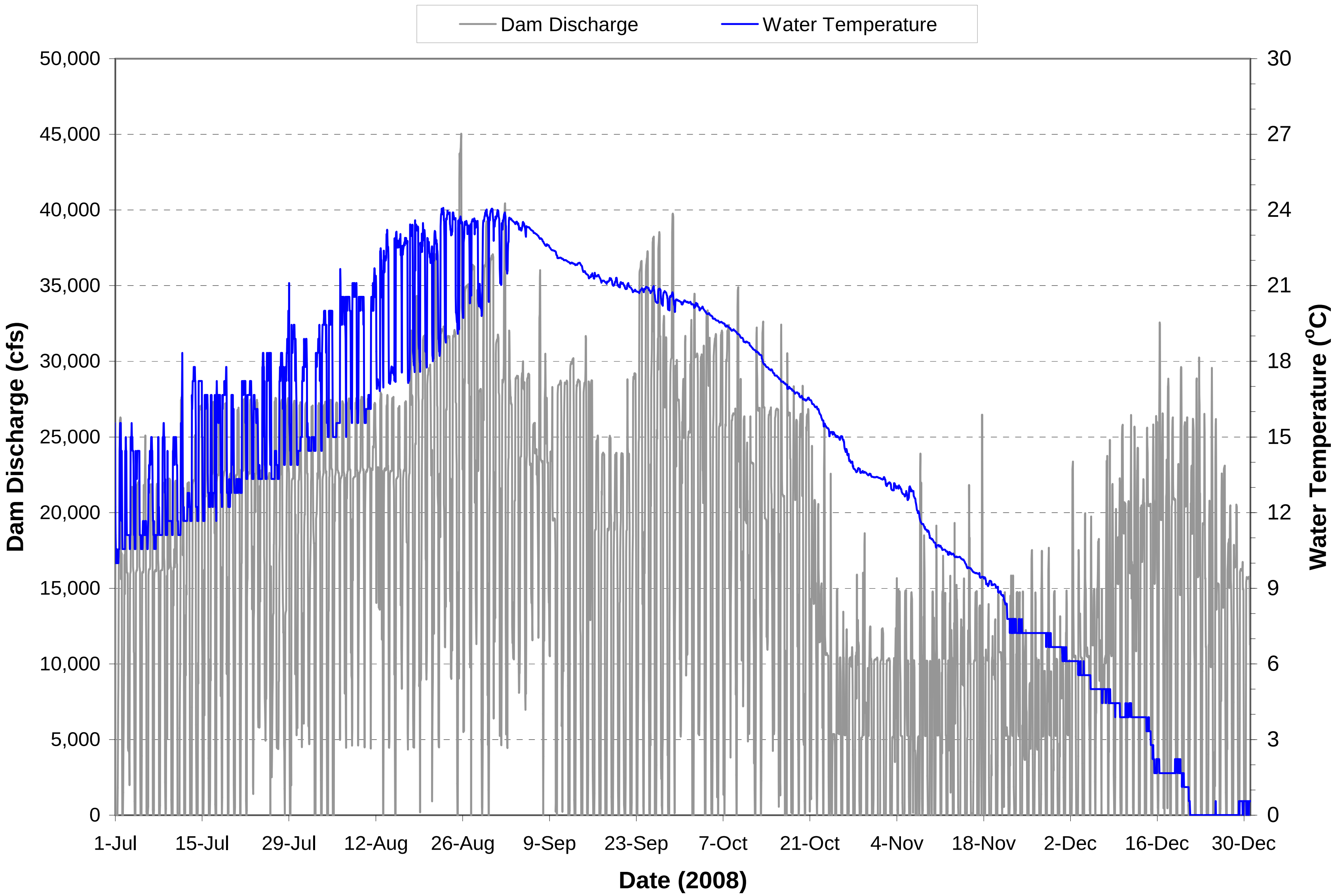


Plate 292. Hourly discharge and water temperature monitored at the Fort Randall powerplant on water discharged through the dam during the period July through December 2008.

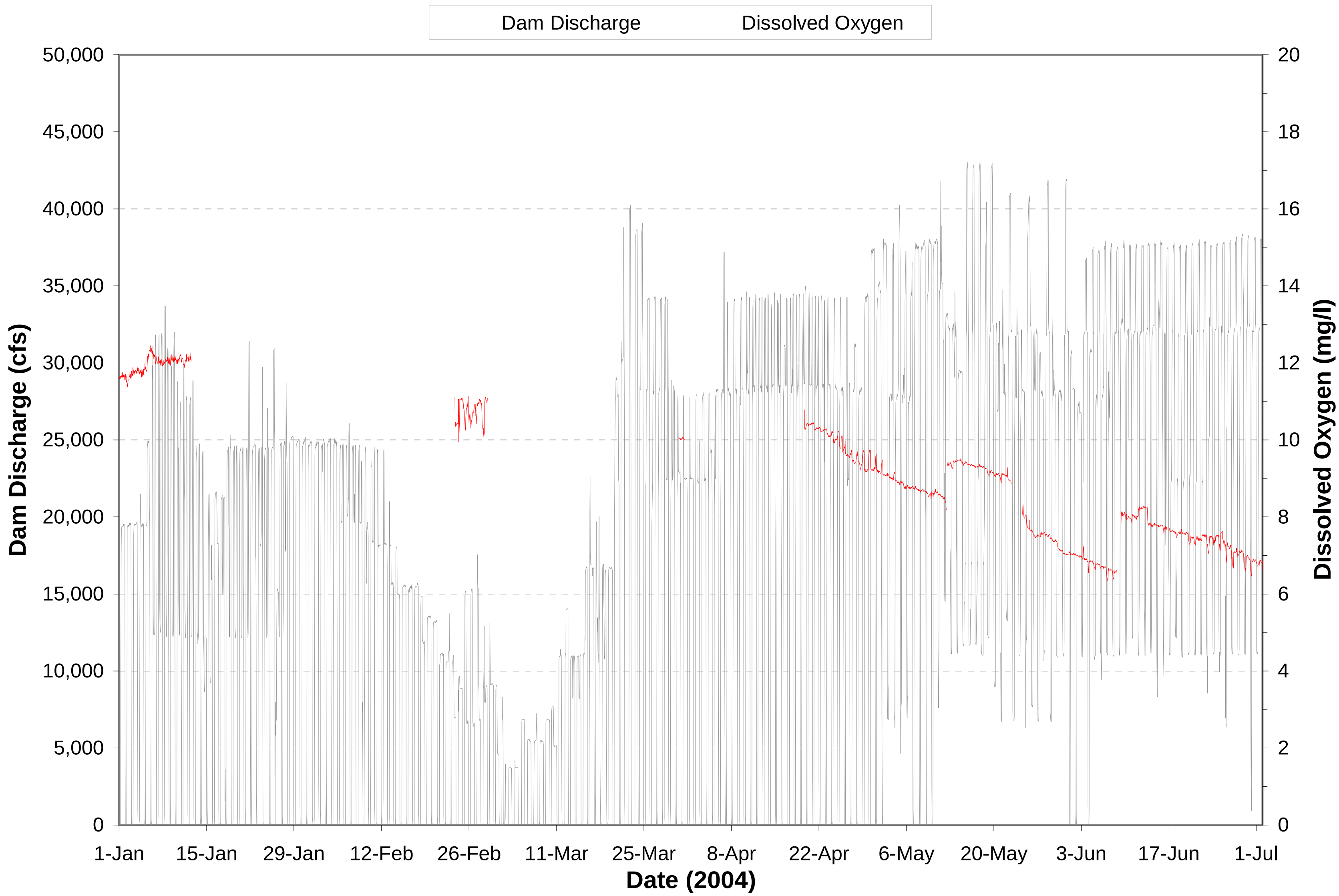


Plate 293. Hourly discharge and dissolved oxygen concentrations monitored at the Fort Randall powerplant on water discharged through the dam during the period January through June 2004.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

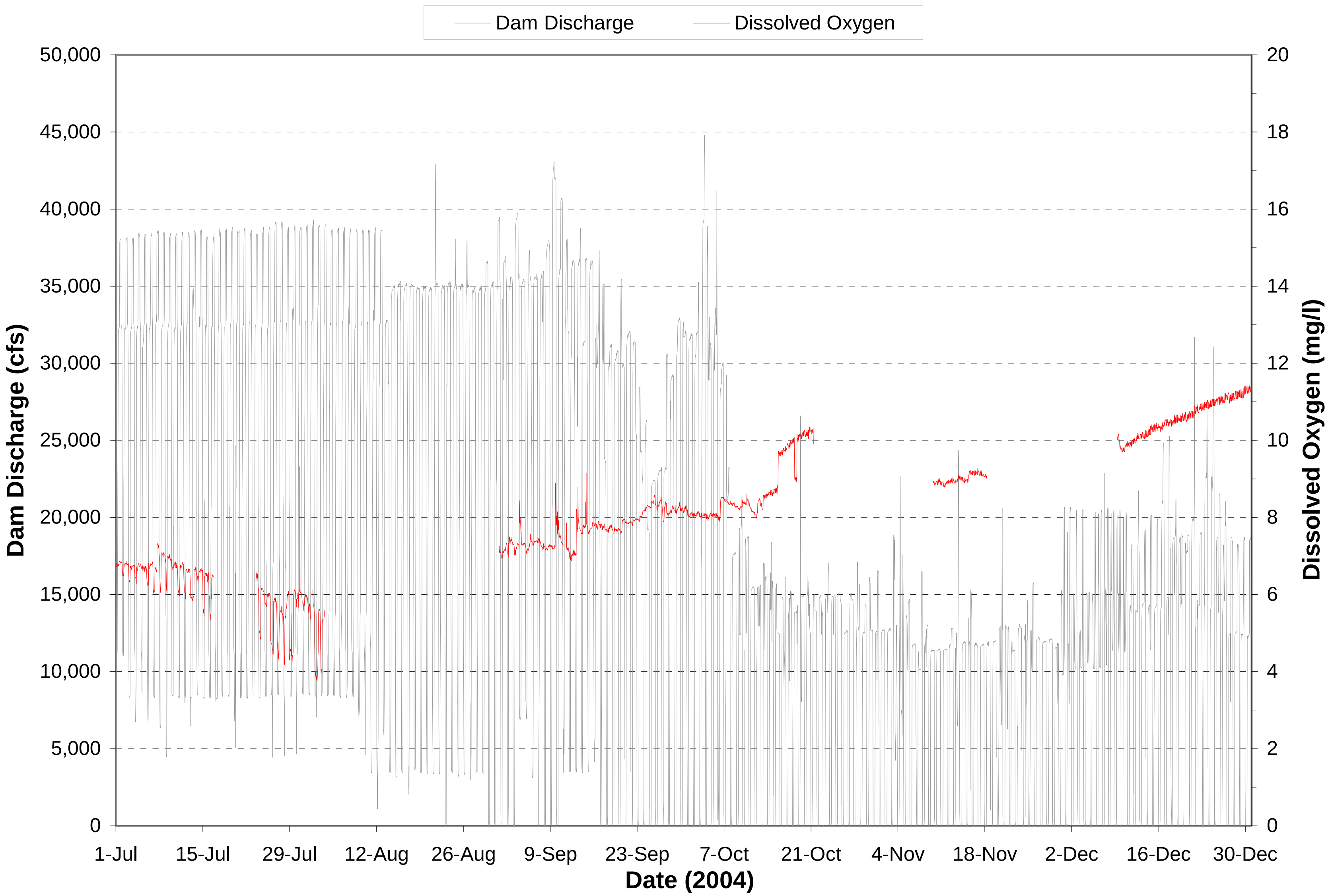


Plate 294. Hourly discharge and dissolved oxygen concentrations monitored at the Fort Randall powerplant on water discharged through the dam during the period July through December 2004.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

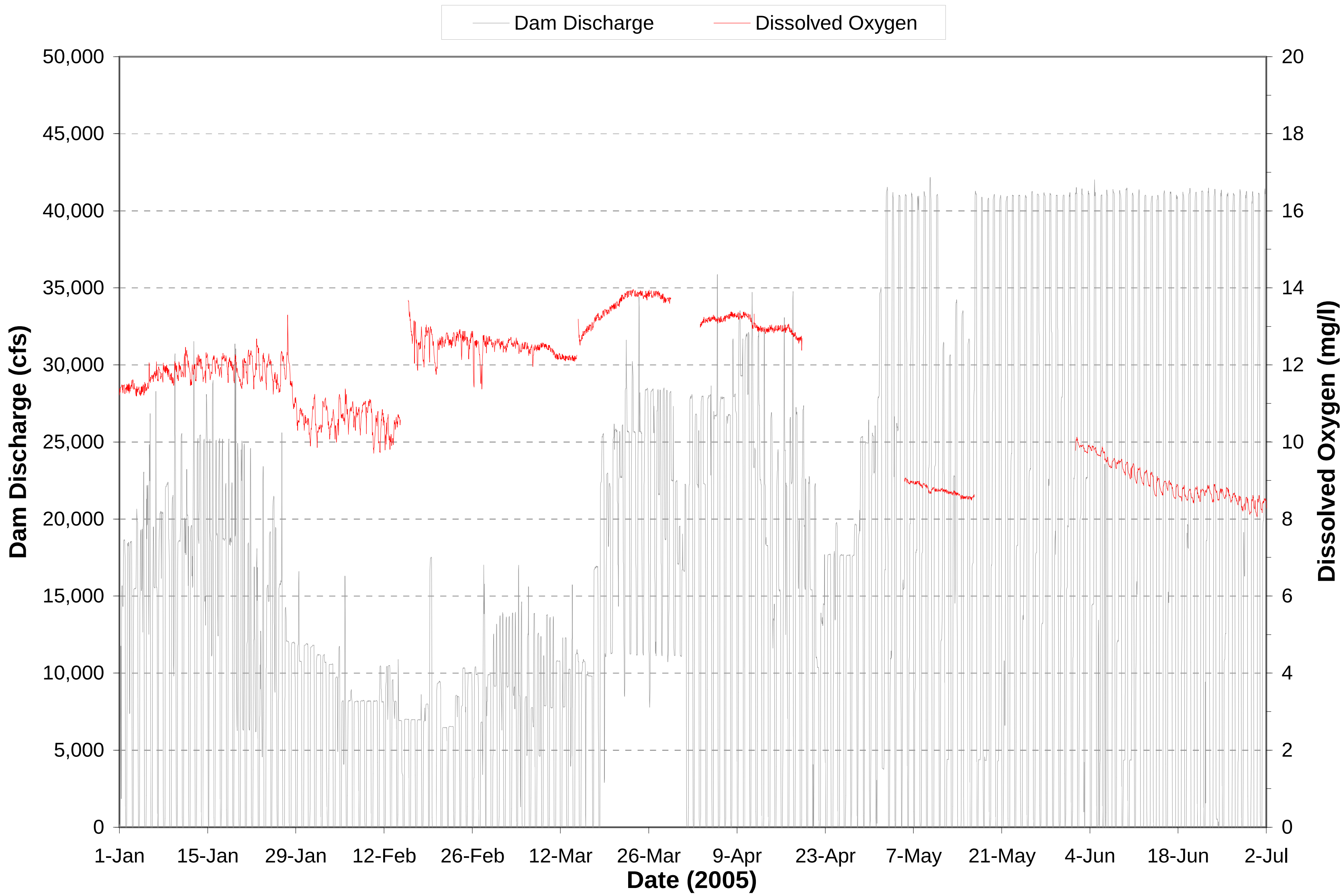


Plate 295. Hourly discharge and dissolved oxygen concentrations monitored at the Fort Randall powerplant on water discharged through the dam during the period January through June 2005.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

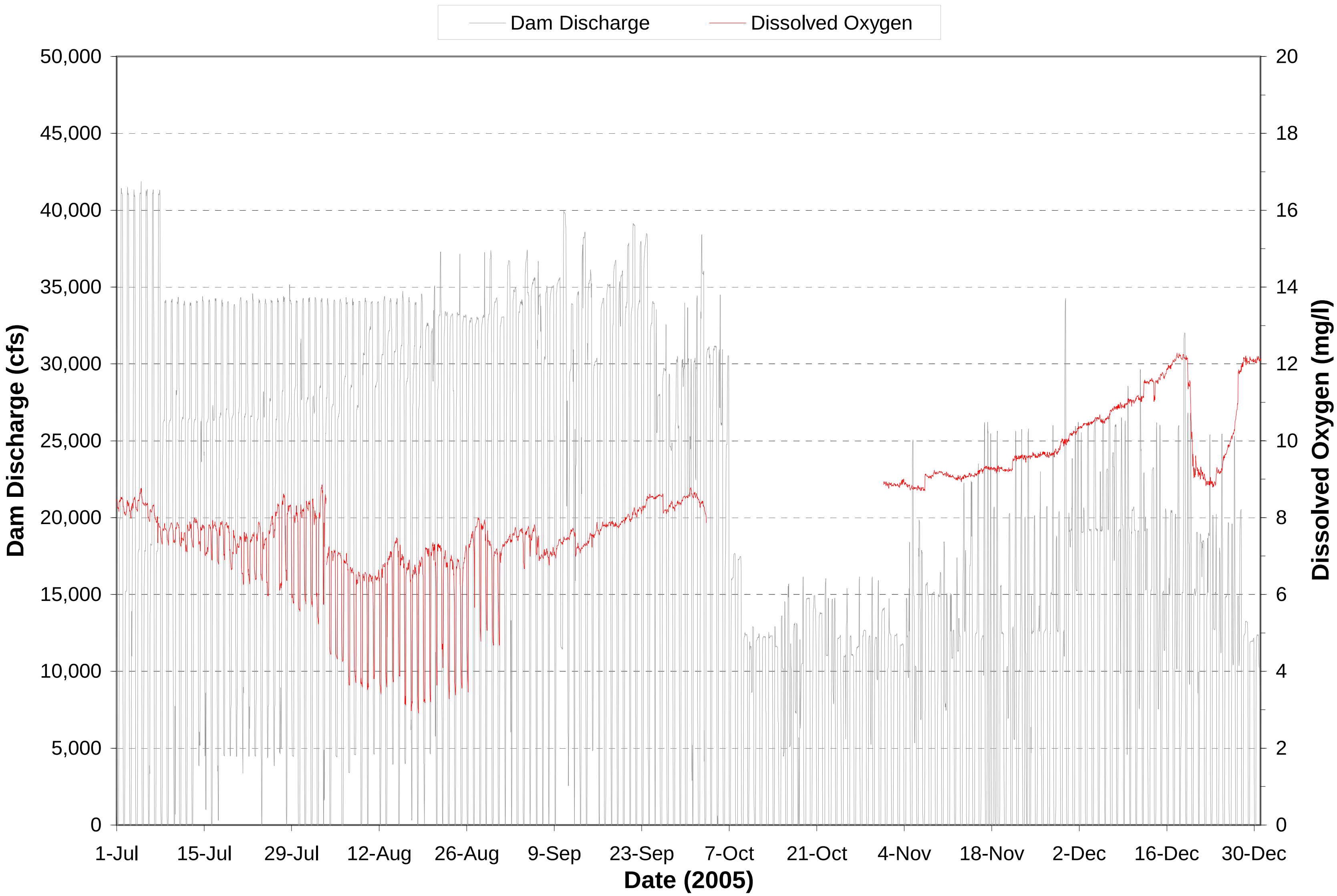


Plate 296. Hourly discharge and dissolved oxygen concentrations monitored at the Fort Randall powerplant on water discharged through the dam during the period July through December 2005.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

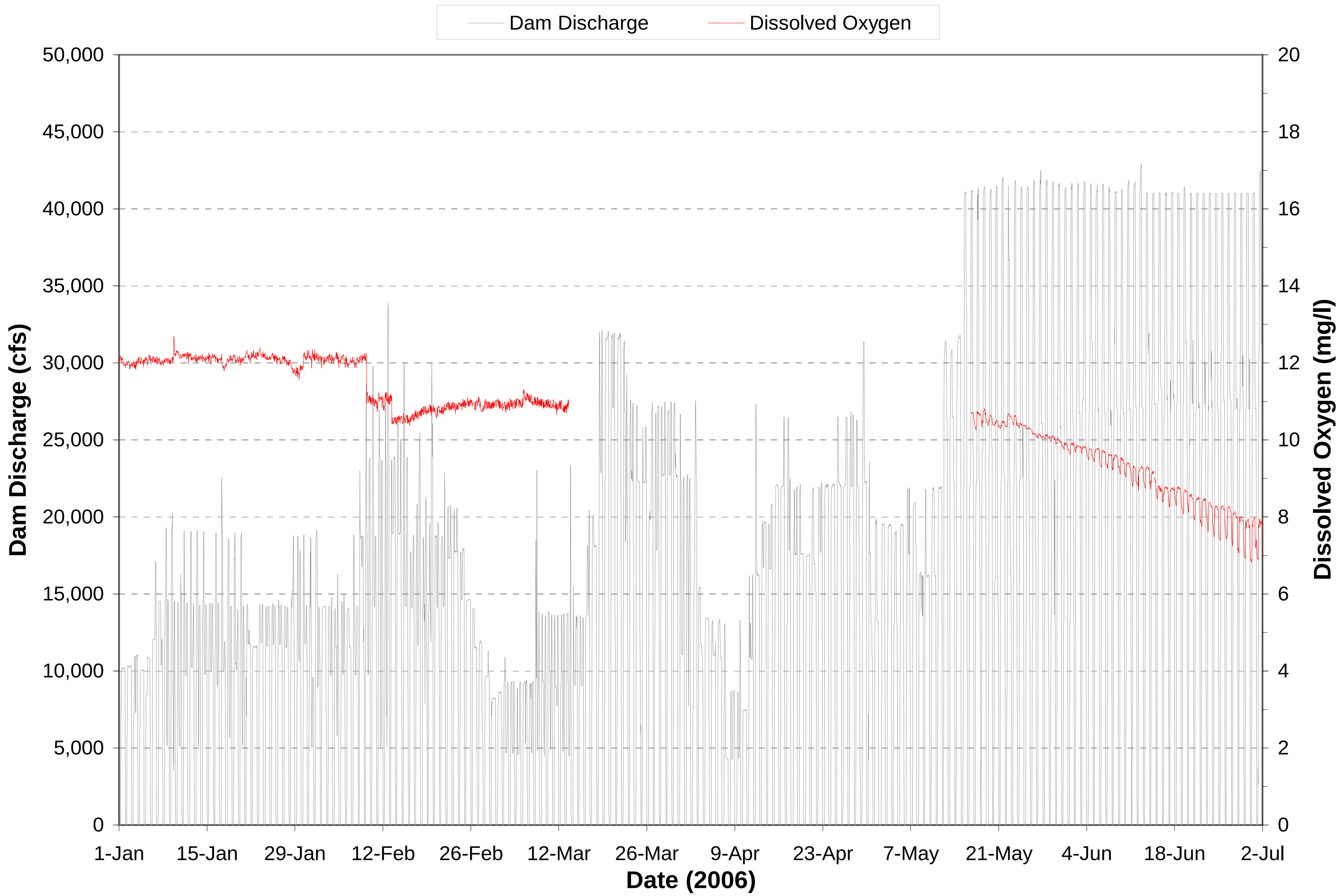


Plate 297. Hourly discharge and dissolved oxygen concentrations monitored at the Fort Randall powerplant on water discharged through the dam during the period January through June 2006.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

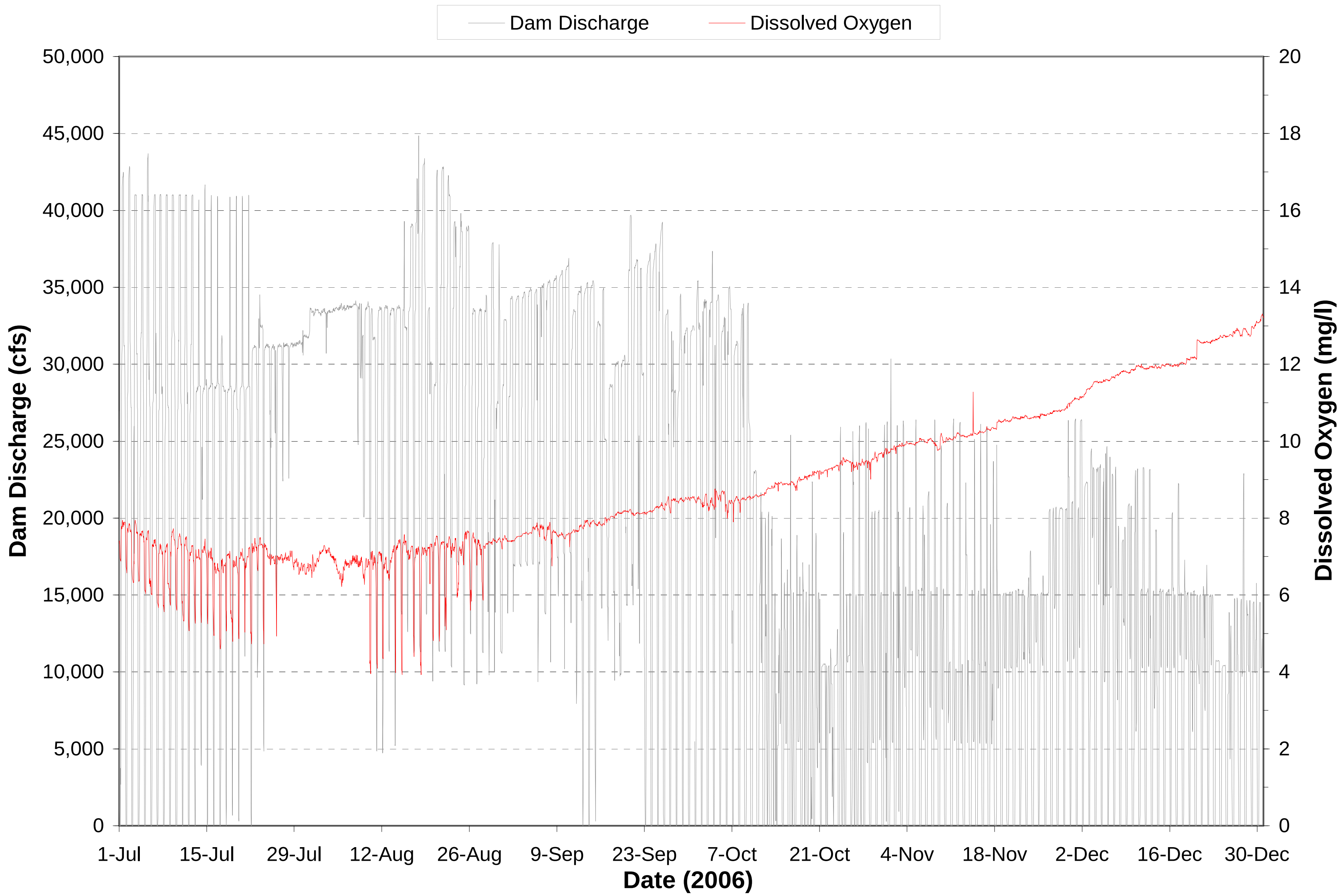


Plate 298. Hourly discharge and dissolved oxygen concentrations monitored at the Fort Randall powerplant on water discharged through the dam during the period July through December 2006.

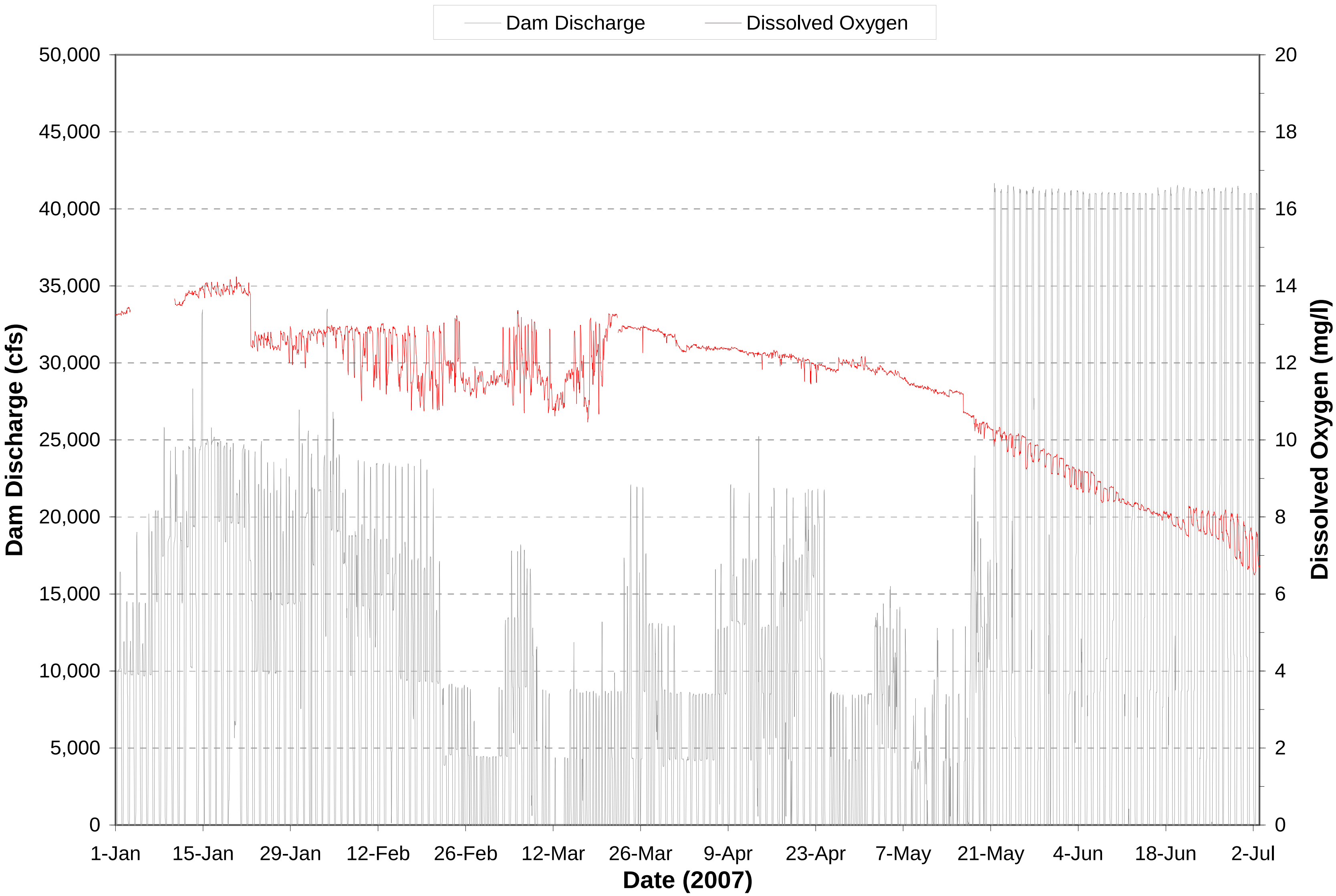


Plate 299. Hourly discharge and dissolved oxygen concentrations monitored at the Fort Randall powerplant on water discharged through the dam during the period January through June 2007.
(Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.)

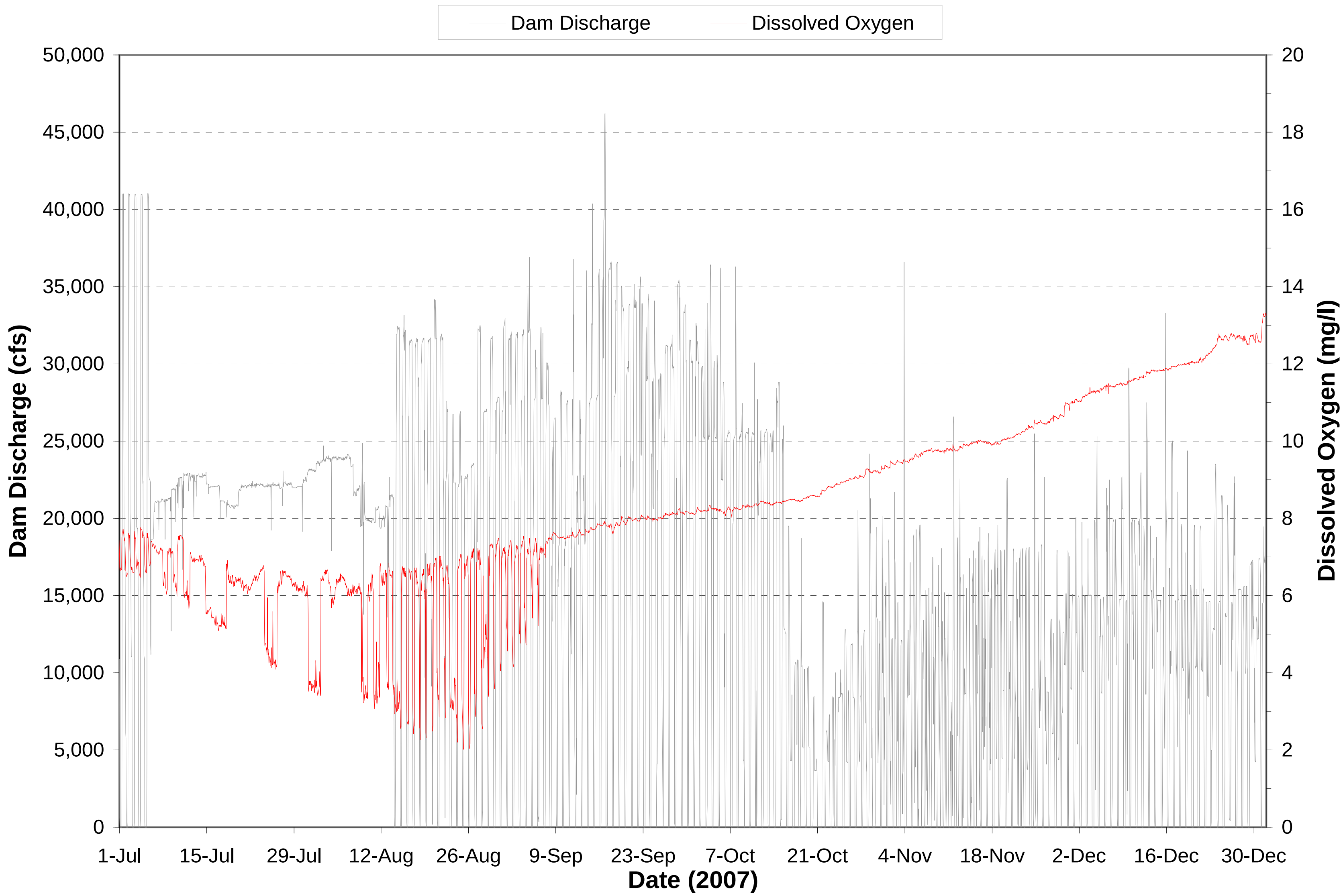


Plate 300. Hourly discharge and dissolved oxygen concentrations monitored at the Fort Randall powerplant on water discharged through the dam during the period July through December 2007.

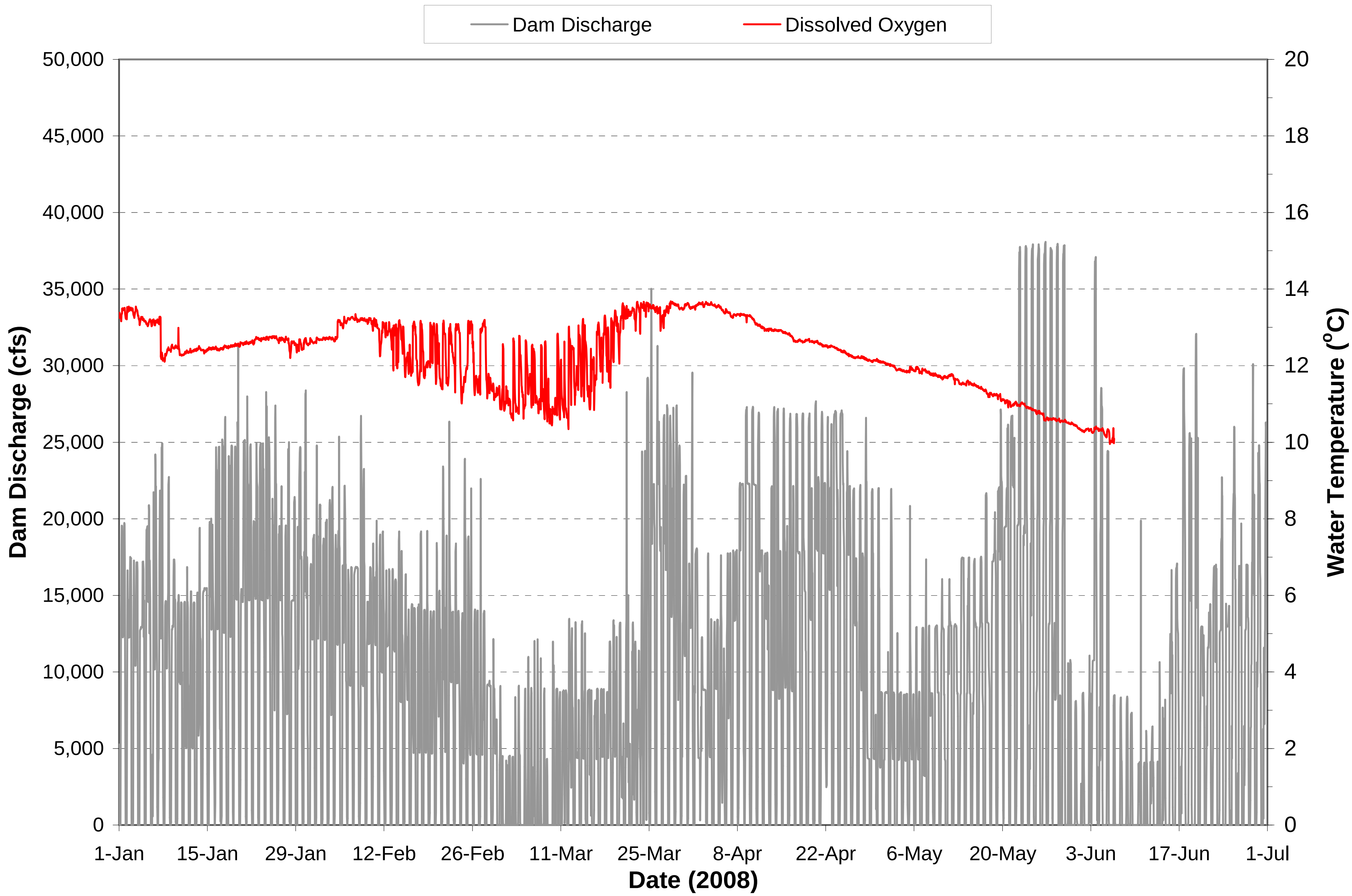


Plate 301. Hourly discharge and dissolved oxygen concentrations monitored at the Fort Randall powerplant on water discharged through the dam during the period January through June 2007.
(Note: The dissolved oxygen monitoring probe malfunctioned in June and no measurements were collected through the end of 2008.)

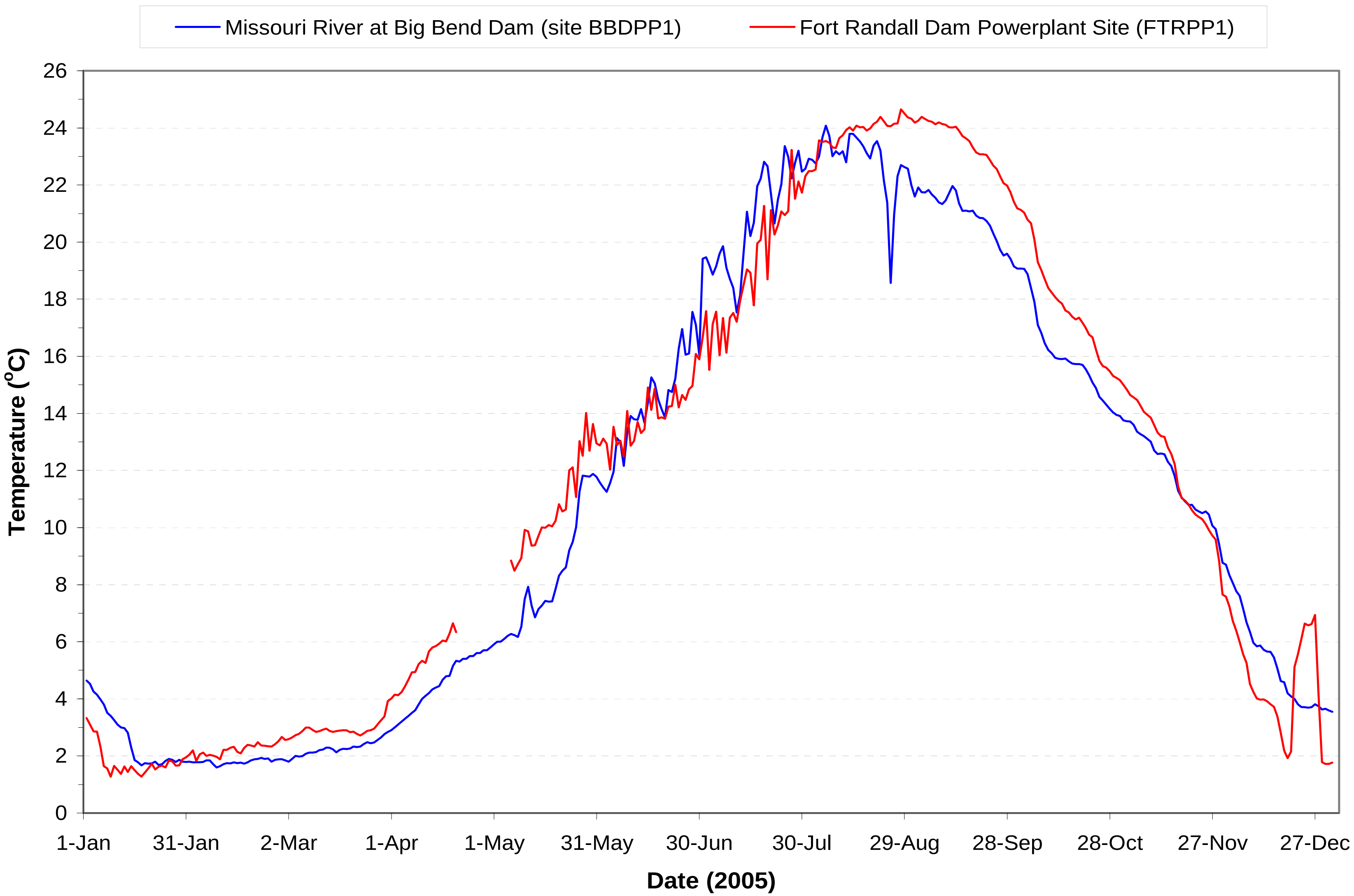


Plate 302. Mean daily water temperatures monitored at the Fort Randall Powerplant (i.e., site FTRPP1) and the Missouri River at Big Bend Dam (i.e., site BBDPP1) during 2005.
(Note: Gaps in temperature plots are periods when monitoring equipment was not operational.)

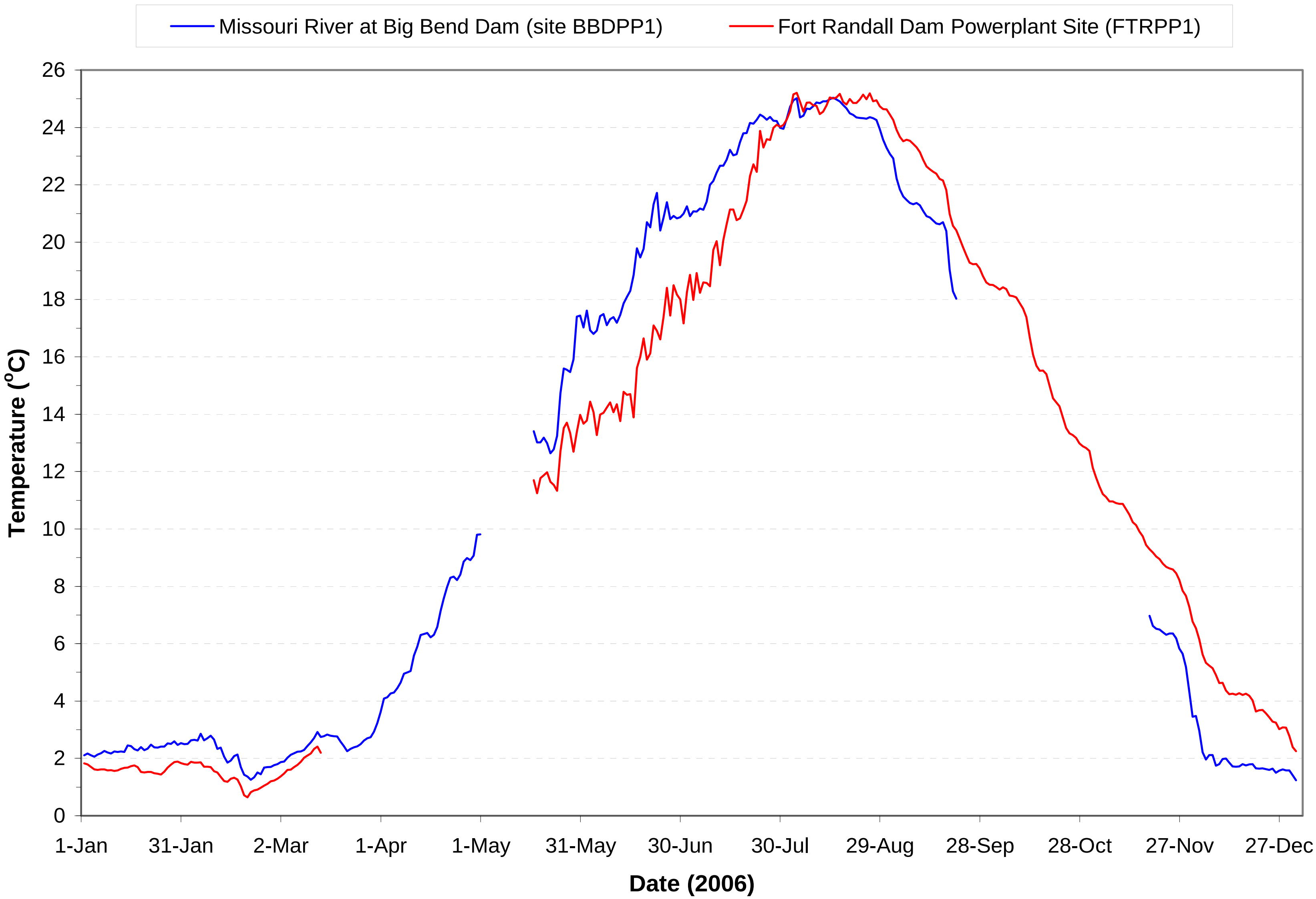


Plate 303. Mean daily water temperatures monitored at the Fort Randall Powerplant (i.e., site FTRPP1) and the Missouri River at Big Bend Dam (i.e., site BBDPP1) during 2006.
(Note: Gaps in temperature plots are periods when monitoring equipment was not operational.)

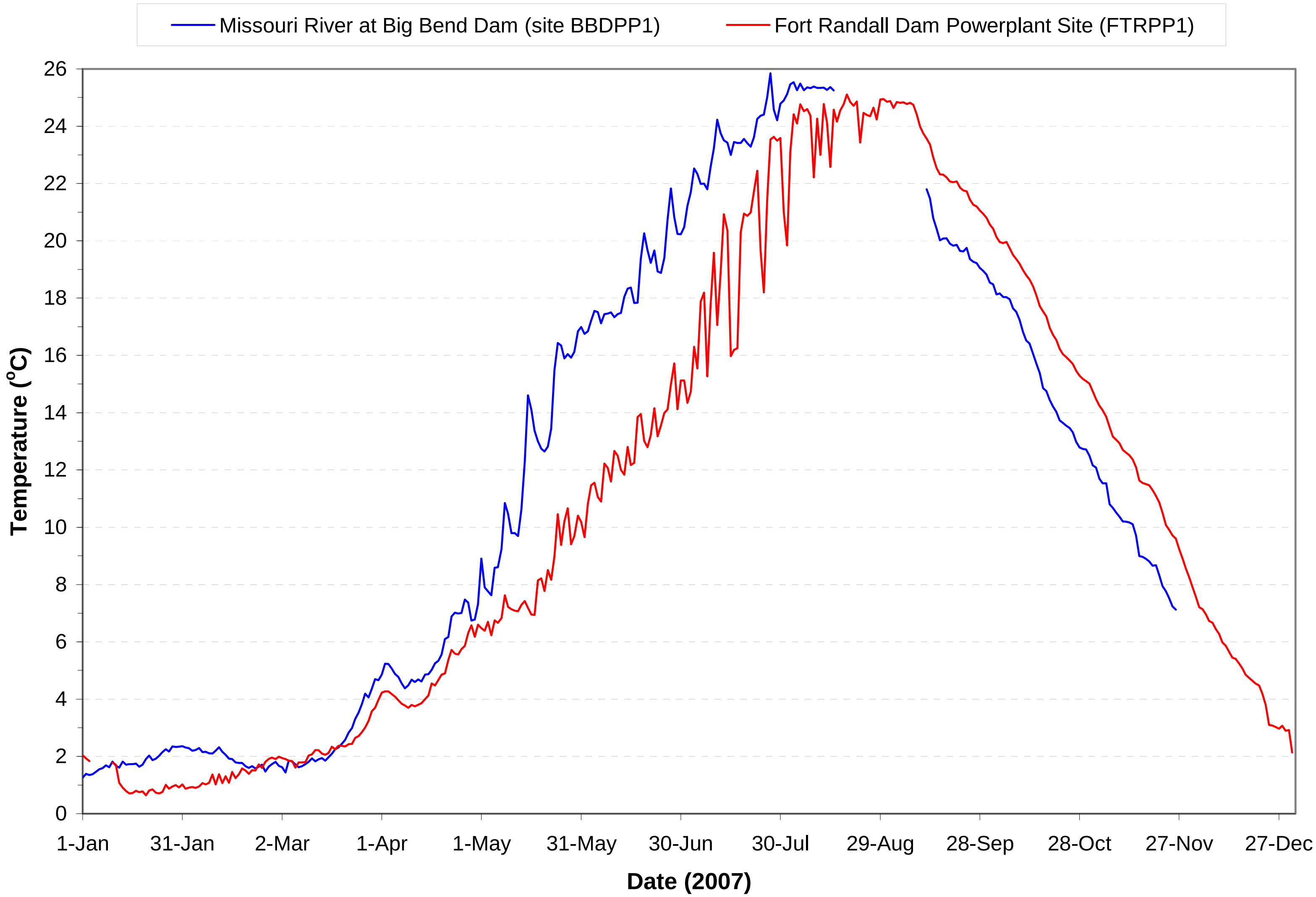


Plate 304. Mean daily water temperatures monitored at the Fort Randall Powerplant (i.e., site FTRPP1) and the Missouri River at Big Bend Dam (i.e., site BBDPP1) during 2007.
(Note: Gaps in temperature plots are periods when monitoring equipment was not operational.).

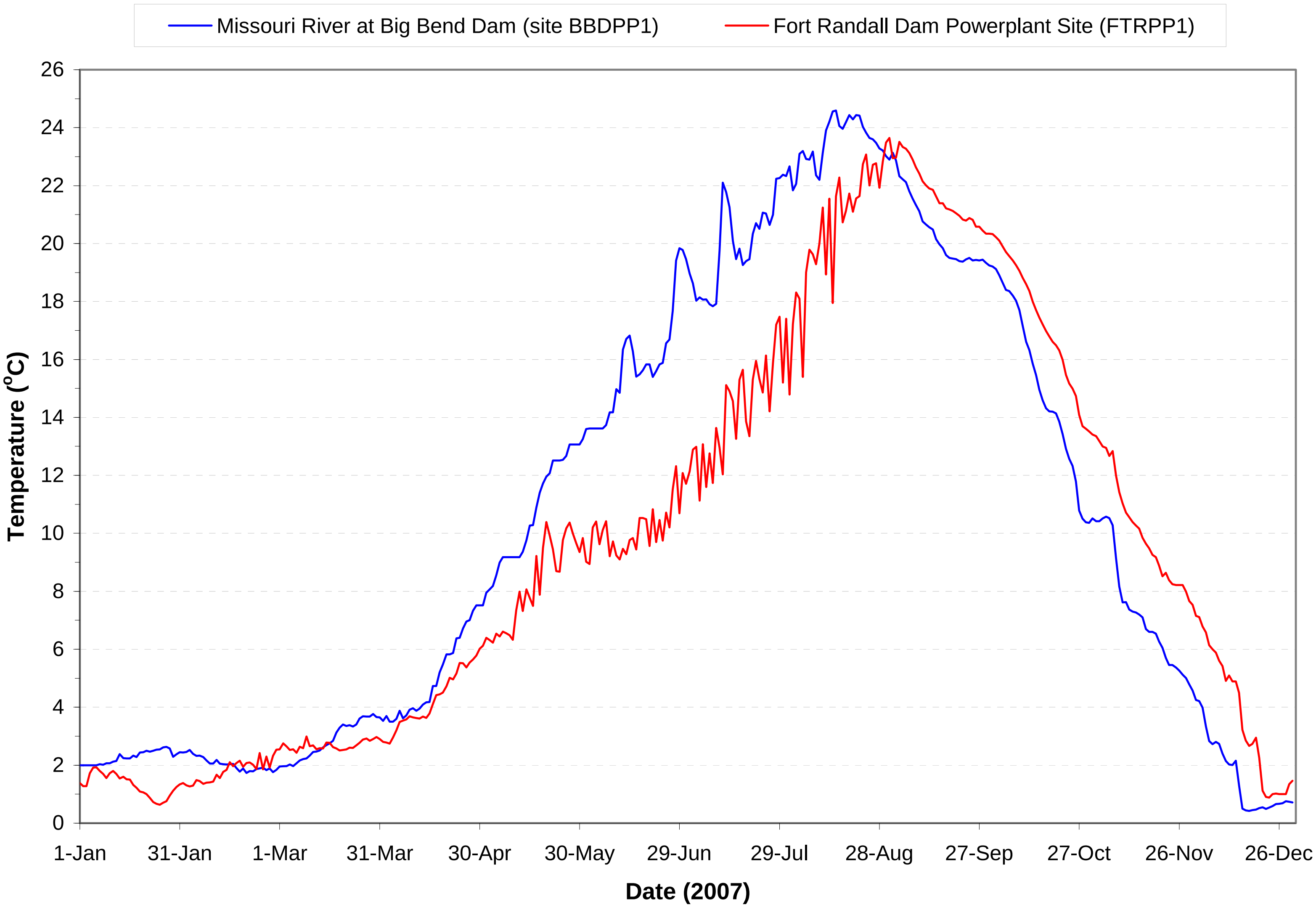


Plate 305. Mean daily water temperatures monitored at the Fort Randall Powerplant (i.e., site FTRPP1) and the Missouri River at Big Bend Dam (i.e., site BBDPP1) during 2008.

Plate 306. Summary of water quality conditions monitored in the Missouri River at the Fort Randall Dam tailwaters (i.e., site FTRRRTW1) during the 5-year period of 2004 through 2008.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit[A]	No. of Obs.	Mean[B]	Median	Min.	Max.	State WQS Criteria[C]	No. of WQS Exceedences	Percent WQS Exceedence
Streamflow (cfs)	1	83	21,027	20,000	3,520	42,400	-----	-----	-----
Water Temperature (C)	0.1	83	13.2	13.9	-0.1	26.2	27[1,4]	0	0%
Dissolved Oxygen (mg/l)	0.1	82	10.0	9.9	4.9	16.9	≥ 5[1,5]	1	1%
Dissolved Oxygen (% Sat.)	0.1	82	94.7	96.2	57.6	117.4	-----	-----	-----
pH (S.U.)	0.1	81	8.3	8.3	6.8	8.6	6 5[1,2,5], 9.0[1,2,4], 9.5[3,4]	0	0%
Specific Conductance (umho/cm)	1	82	687	695	535	803	-----	-----	-----
Oxidation-Reduction Potential	1	28	395	394	305	516	-----	-----	-----
Alkalinity, Total (mg/l)	7	82	171	170	130	223	-----	-----	-----
Ammonia, Total (mg/l)	0.02	82	-----	0.05	n.d.	0.62	4.7 [1,4,7], 1.4 [1,6,7]	0	0%
Carbon, Total Organic (mg/l)	0.05	78	3.4	3.1	1.6	16.1	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	82	9	9	n.d.	53	-----	-----	-----
Chloride (mg/l)	1	82	12	11	5	31	175[1,4], 100[1,6], 438[2,4], 250[2,6]	0	0%
Dissolved Solids, Total (mg/l)	5	47	496	480	440	840	1,750[2,4], 1,000[2,7], 3,500[3,4], 2,000[3,6]	0	0%
Hardness, Total (mg/l)	0.4	18	226	228	186	242	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	82	0.5	0.4	n.d.	3.2	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	81	-----	n.d.	n.d.	1.40	10[2,4]	0	0%
Phosphorus, Total (mg/l)	0.02	81	-----	0.03	n.d.	0.73	-----	-----	-----
Suspended Solids, Total (mg/l)	4	82	-----	n.d.	n.d.	178	158[1,4], 90[1,6]	1, 1	1%, 1%
Turbidity (NTU)	1	83	12	7	n.d.	67	-----	-----	-----
Aluminum, Dissolved (mg/l)	25	7	-----	n.d.	n.d.	50	-----	-----	-----
Antimony, Dissolved (ug/l)	0.5	8	-----	n.d.	n.d.	0.7	5.6[10]	0	0%
Arsenic, Dissolved (ug/l)	1	19	-----	n.d.	n.d.	3	340[8], 150[9], 0.018[10]	b.d.	b.d.
Barium, Dissolved (ug/l)	5	7	37	37	31	44	-----	-----	-----
Beryllium, Dissolved (ug/l)	2	8	-----	n.d.	n.d.	n.d.	4[10]	0	0%
Cadmium, Dissolved (ug/l)	0.2	19	-----	n.d.	n.d.	n.d.	11.8[8], 4.8[9], 5[10]	0	0%
Chromium, Dissolved (ug/l)	10	19	-----	n.d.	n.d.	n.d.	3,630[8], 174[9]	0	0%
Copper, Dissolved (ug/l)	2	19	-----	n.d.	n.d.	5	31.3[8], 19.4[9], 1,300[10]	0	0%
Lead, Dissolved (ug/l)	0.5	19	-----	n.d.	n.d.	0.8	242[8], 9.4[9]	0	0%
Mercury, Dissolved (ug/l)	0.02	19	-----	n.d.	n.d.	n.d.	1.7[8], 0.05[9]	0	0%
Mercury, Total (ug/l)	0.02	19	-----	n.d.	n.d.	n.d.	0.77[9]	0	0%
Nickel, Dissolved (ug/l)	10	19	-----	n.d.	n.d.	n.d.	966[8], 107[9], 610[10]	0	0%
Selenium, Total (ug/l)	1	19	-----	n.d.	n.d.	4	-----	-----	-----
Silver, Dissolved (ug/l)	1	19	-----	n.d.	n.d.	n.d.	14.7[8]	0	0%
Zinc, Dissolved (ug/l)	10	19	-----	n.d.	n.d.	26	247[8,9], 7,400[10]	0	0%
Alachlor, Total (ug/l)[D]	0.05	60	-----	n.d.	n.d.	n.d.	-----	-----	-----
Atrazine, Total (ug/l)[D]	0.05	69	-----	n.d.	n.d.	0.11	-----	-----	-----
Metolachlor, Total (ug/l)[D]	0.05	69	-----	n.d.	n.d.	0.30	-----	-----	-----
Pesticide Scan (ug/l)[E]	0.05	13					-----	-----	-----
Profluralin		4	-----	n.d.	n.d.	0.16	-----	-----	-----

n.d. = Not detected. b.d. = Criterion below detection limit.

(A) Detection limits given for the parameters Stream Flow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for the protection of warmwater permanent fish life propagation waters.
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of commerce and industry waters.
- (4) Daily maximum criterion (monitoring results directly comparable to criterion).
- (5) Daily minimum criterion (monitoring results directly comparable to criterion).
- (6) 30-day average criterion (monitoring results not directly comparable to criterion).
- (7) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (8) Acute (CMC) criterion for the protection of freshwater aquatic life.
- (9) Chronic (CCC) criterion for the protection of freshwater aquatic life.
- (10) Criterion for the protection of human health.

Note: Some of South Dakota's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

(D) Immunoassay analysis.

(E) The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, cycloate, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, isopropalin, metolachlor, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, phorate, profluralin, prometon, propachlor, propazine, simazine, terbufos, triallate, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

Plate 307. Summary of water quality conditions monitored in the Missouri River near Verdel, Nebraska (i.e., site MORRR0851) at RM851 during the 5-year period of 2004 through 2008.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit[A]	No. of Obs.	Mean[B]	Median	Min.	Max.	State WQS Criteria[C]	No. of WQS Exceedences	Percent WQS Exceedence
Streamflow (cfs)	1	78	22,052	22,010	3,012	41,299	-----	-----	-----
Water Temperature (C)	0.1	77	14.5	15.5	0.5	28.6	27[1,2,6], 29[1,2,6]	1, 0	1%, 0%
Dissolved Oxygen (mg/l)	0.1	76	9.8	9.4	6.4	13.8	5[1,7]	0	0%
Dissolved Oxygen (% Sat.)	0.1	76	96.8	98.0	73.3	118.8	-----	-----	-----
Specific Conductance (umho/cm)	1	77	687	701	432	814	2,000[4]	0	0%
pH (S.U.)	0.1	76	8.3	8.3	7.6	8.7	6 5[1,3,7], 9.0[1,3,6], 9.5[5,6]	0	0%
Oxidation-Reduction Potential	1	27	388	381	315	486	-----	-----	-----
Alkalinity, Total (mg/l)	7	77	169	170	118	220	-----	0	0%
Ammonia, Total (mg/l)	0.02	77	-----	0.05	n.d.	0.41	4.7 [1,6,9], 1.4 [1,8,9]	0	0%
Carbon, Total Organic (mg/l)	0.05	75	3.3	3.0	1.6	12.8	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	77	9	8	n.d.	47	-----	-----	-----
Chloride (mg/l)	1	76	11	11	5	31	175[1,6], 100[1,8], 438[3,6], 250[3,8]	0	0%
Dissolved Solids, Total (mg/l)	5	43	484	480	310	780	1,750[3,6], 1,000[3,8], 3,500[5,6], 2,000[5,8]	9[6]	27%[6]
Hardness, Total (mg/l)	0.4	14	224	228	167	242	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	77	0.5	0.4	n.d.	3.4	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	77	-----	n.d.	n.d.	0.50	10[3,6], 100[4,6]	0	0%
Phosphorus, Total (mg/l)	0.02	76	0.05	0.03	n.d.	0.75	-----	-----	-----
Suspended Solids, Total (mg/l)	4	77	-----	5	n.d.	230	158[1,5], 90[1,8]	1, 1	1%, 1%
Turbidity (NTU)	1	76	15	10	n.d.	129	-----	-----	-----
Aluminum, Dissolved (mg/l)	25	5	-----	n.d.	n.d.	n.d.	750[10], 87[11], 200[12]	0	0%
Antimony, Dissolved (ug/l)	0.5	6	-----	n.d.	n.d.	2	88[10], 30[11], 6[12]	0	0%
Arsenic, Dissolved (ug/l)	1	17	-----	n.d.	n.d.	4	340[10], 16.7[11], 10[12]	0	0%
Barium, Dissolved (ug/l)	5	6	38	38	33	43	2,000[11]	0	0%
Beryllium, Dissolved (ug/l)	2	7	-----	n.d.	n.d.	n.d.	130[10], 5.3[11], 4[12]	0	0%
Cadmium, Dissolved (ug/l)	0.2	17	-----	n.d.	n.d.	n.d.	13[10], 0.44[11], 5[12]	0	0%
Chromium, Dissolved (ug/l)	10	17	-----	n.d.	n.d.	n.d.	1,162[10], 151[11], 100[12]	0	0%
Copper, Dissolved (ug/l)	2	17	-----	n.d.	n.d.	3	29[10], 18[11], 1,000[12]	0	0%
Iron, Dissolved (ug/l)	40	9	-----	n.d.	n.d.	100	1,000[11]	0	0%
Lead, Dissolved (ug/l)	0.5	17	-----	n.d.	n.d.	0.8	156[10], 6 1[11], 15[12]	0	0%
Mercury, Dissolved (ug/l)	0.02	17	-----	n.d.	n.d.	n.d.	1.4[10]	0	0%
Mercury, Total (ug/l)	0.02	17	-----	n.d.	n.d.	n.d.	0.77[11], 2[12]	0	0%
Nickel, Dissolved (ug/l)	10	17	-----	n.d.	n.d.	n.d.	940[10], 104[11], 100[12]	0	0%
Selenium, Total (ug/l)	1	17	-----	n.d.	n.d.	4	20[4,10], 5[11], 50[12]	0	0%
Silver, Dissolved (ug/l)	1	17	-----	n.d.	n.d.	n.d.	14[10], 100[12]	0	0%
Thallium, Dissolved (ug/l)	0.5	6	-----	n.d.	n.d.	n.d.	1,400[10], 6.3[11], 2[12]	0	0%
Zinc, Dissolved (ug/l)	5	17	-----	n.d.	n.d.	8	236[10,11], 5,000[12]	0	0%
Acetochlor, Total (ug/l)[D]	0.05	9	-----	n.d.	n.d.	0.10	-----	-----	-----
Alachlor, Total (ug/l)[D]	0.05	58	-----	n.d.	n.d.	n.d.	760[10], 76[11], 2[12]	0	0%
Atrazine, Total (ug/l)[D]	0.05	67	-----	n.d.	n.d.	0.27	330[10], 12[11], 3[12]	0	0%
Metolachlor, Total (ug/l)[D]	0.05	67	-----	n.d.	n.d.	0.20	390[10], 100[11]	0	0%
Pesticide Scan (ug/l)[E]	0.05						-----	-----	-----
Profluralin		4	-----	n.d.	n.d.	0.20	-----	-----	-----

n.d. = Not detected.

(A) Detection limits given for the parameters Stream Flow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for the protection of Warmwater Permanent Fish Life Propagation Waters (South Dakota) or Class I Warmwater Aquatic Life (Nebraska).
- (2) South Dakota's temperature criterion is 27 C and Nebraska's is 29 C.
- (3) Criteria for the protection of domestic water supply waters.
- (4) Criteria for the protection of agricultural water supply waters.
- (5) Criteria for the protection of commerce and industry waters.
- (6) Daily maximum criterion (monitoring results directly comparable to criterion).
- (7) Daily minimum criterion (monitoring results directly comparable to criterion).
- (8) 30-day average criterion (monitoring results not directly comparable to criterion).
- (9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (10) Acute (CMC) criterion for the protection of freshwater aquatic life.
- (11) Chronic (CCC) criterion for the protection of freshwater aquatic life.
- (12) Criterion for the protection of human health.

Note: Some of South Dakota's and Nebraska's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

(D) Immunoassay analysis.

(E) The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, cycloate, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, isopropalin, metolachlor, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, phorate, profluralin, prometon, propachlor, propazine, simazine, terbufos, triallate, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

Plate 308. Summary of monthly (May through September) water quality conditions monitored in Gavins Point Reservoir near Gavins Point Dam (Site GPTLK0811A) during the 5-year period 2004 through 2008.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	25	1206.6	1206.5	1205.5	1207.7	-----	-----	-----
Water Temperature (C)	0.1	310	21.3	22.3	10.0	27.8	27[1,2,6], 29[1,2,6]	2, 0	1%, 0%
Dissolved Oxygen (mg/l)	0.1	310	7.8	8.1	1.4	13.1	5[1,7]	24	8%
Dissolved Oxygen (% Sat.)	0.1	310	91.3	95.5	16.7	151.5	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	262	8.3	8.3	4 1	13.1	5[1,7]	2	1%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	48	5.0	4.8	1.4	9.6	5[1,7]	27[F]	56%[F]
Specific Conductance (umho/cm)	1	309	677	692	555	761	2,000[4]	0	0%
pH (S.U.)	0.1	287	8.4	8.5	6.9	9.0	6.5[1,3,7], 9.0[1,3,6], 9.5[5,6]	0	0%
Turbidity (NTUs)	1	308	20	15	2	132	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	310	344	347	266	452	-----	-----	-----
Secchi Depth (in.)	1	25	35	34	18	52	-----	-----	-----
Alkalinity, Total (mg/l)	7	48	162	161	130	186	-----	-----	-----
Ammonia, Total (mg/l)	0.02	48	-----	0.06	n.d.	0.35	3.5 [1,6,9], 0.68 [1,8,9]	0	0%
Carbon, Total Organic (mg/l)	0.05	46	3.3	3.3	2.0	6.1	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	30	12	12	5	19	-----	-----	-----
Chloride (mg/l)	1	32	10	10	8	14	175[1,6], 100[1,8], 438[3,6], 250[3,8]	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	305	9.2*	9	n.d.	37	8[10]	159	52%
Chlorophyll *a* (ug/l) – Lab Determined	1	22	10.8*	11	1	53	8[10]	12	55%
Dissolved Solids, Total (mg/l)	5	34	467	460	400	576	1,750[3,6], 1,000[3,8], 3,500[5,6], 2,000[5,8], 500[11]	0, 0, 0, 0, 5	0%, 0%, 0%, 0%, 15%
Iron, Dissolved (ug/l)	40	20	-----	n.d.	n.d.	156	1,000[8]	0	0%
Iron, Total (ug/l)	40	20	368	342	100	727	300[11]	12	60%
Manganese, Dissolved (ug/l)	2	20	49	8	n.d.	225	1,000[8]	0	0%
Manganese, Total (ug/l)	2	20	105	60	20	329	50[11]	12	60%
Nitrogen, Total Kjeldahl (mg/l)	0.1	48	0.5	0.4	n.d.	1.5	-----	-----	-----
Nitrogen, Total (mg/l)	0.1	48	0.49	0.4	n.d.	1.5	0 57[10]	14	29%
Nitrate-Nitrite N, Total (mg/l)	0.02	48	-----	n.d.	n.d.	0.30	10[3,6], 100[4,6]	0	0%
Phosphorus, Dissolved (mg/l)	0.01	28	-----	n.d.	n.d.	0.07	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	48	0.056	0.05	n.d.	0.23	0.06[10]	11	23%
Phosphorus-Ortho, Dissolved (mg/l)	0.01	48	-----	n.d.	n.d.	0.04	-----	-----	-----
Sulfate (mg/l)	1	34	200	196	177	223	875[3,6], 500[3,8], 250[11]	0	0%
Suspended Solids, Total (mg/l)	4	48	9	8	n.d.	32	158[1,6], 90[1,8]	0	0%
Microcystin, Total (ug/l)	0.2	19	-----	n.d.	n.d.	14	-----	-----	-----

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, Oxidation-Reduction Potential, Turbidity, Chlorophyll a (Field Probe), and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for the protection of Warmwater Permanent Fish Life Propagation Waters (South Dakota) or Class I Warmwater Aquatic Life (Nebraska).
- (2) South Dakota's temperature criterion is 27 C and Nebraska's is 29 C.
- (3) Criteria for the protection of domestic water supply waters.
- (4) Criteria for the protection of agricultural water supply waters.
- (5) Criteria for the protection of commerce and industry waters.
- (6) Daily maximum criterion (monitoring results directly comparable to criterion).
- (7) Daily minimum criterion (monitoring results directly comparable to criterion).
- (8) 30-day average criterion (monitoring results not directly comparable to criterion).
- (9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (10) Nutrient criteria – Gavins Point Reservoir is classified R9 by Nebraska for application of nutrient criteria.
- (11) The criteria for total dissolved solids, iron, and manganese are listed by the State of Nebraska to protect the beneficial use of public drinking water. Where the natural background level is greater than these criteria, the State of Nebraska states that the background level is to be used in place of the criteria. The elevated levels are believed indicative of natural background conditions and are not considered a water quality standards "violation".

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5 C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1 C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5 C occurs over a 1-meter depth increment.

(F) According to South Dakota's beneficial use support decision criteria, dissolved oxygen levels are not considered impaired if a region exists in the depth profile (i.e , epilimnion) where the dissolved oxygen levels are ≥5 mg/l. Nebraska's dissolved oxygen criteria do not apply to the hypolimnion.

* The highlighted mean values indicate use impairment based on State of Nebraska 2008 Section 303(d) impairment assessment criteria.

Plate 309. Summary of monthly (June through September) water quality conditions monitored in Gavins Point Reservoir near the Weigand Recreation Area (site GPTLK0815DW) during 2008.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	4	1206.4	1206.2	1205.9	1207.4	-----	-----	-----
Water Temperature (C)	0.1	37	22.1	22.3	18.4	25.3	27[1,2,6], 29[1,2,6]	0	0%
Dissolved Oxygen (mg/l)	0.1	37	8.1	7.9	6.3	10.2	5[1,7]	0	0%
Dissolved Oxygen (% Sat.)	0.1	37	95.9	95.5	74.7	121.0	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	27	8.5	8.6	6.3	10.2	5[1,7]	0	0%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	10	6.9	6.8	6.3	7.6	5[1,7]	0	0%
Specific Conductance (umho/cm)	1	37	694	697	662	715	-----	-----	-----
pH (S.U.)	0.1	37	8.2	8.3	7.8	8.5	6.5[1,3,7], 9.0[1,3,6], 9.5[5,6]	0	0%
Turbidity (NTUs)	1	37	31	30	14	71	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	37	323	328	269	392	8[8]	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	37	8.9*	9	4	21	-----	-----	-----
Secchi Depth (in)	1	4	21	20	19	26	-----	-----	-----

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, Oxidation-Reduction Potential, Turbidity, Chlorophyll a (Field Probe), and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for the protection of Warmwater Permanent Fish Life Propagation Waters (South Dakota) or Class I Warmwater Aquatic Life (Nebraska).
- (2) South Dakota's temperature criterion is 27 C and Nebraska's is 29 C.
- (3) Criteria for the protection of domestic water supply waters.
- (4) Criteria for the protection of agricultural water supply waters.
- (5) Criteria for the protection of commerce and industry waters.
- (6) Daily maximum criterion (monitoring results directly comparable to criterion).
- (7) Daily minimum criterion (monitoring results directly comparable to criterion).
- (8) Nutrient criteria – Gavins Point Reservoir is classified R9 by Nebraska for application of nutrient criteria.

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5 C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1 C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5 C occurs over a 1-meter depth increment.

* The highlighted mean value indicates use impairment based on State of Nebraska 2008 Section 303(d) impairment assessment criteria.

Plate 310. Summary of monthly (May through September) water quality conditions monitored in Gavins Point Reservoir near the Bloomfield Recreation Area (Site GPTLK0819DW) during 2008.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	4	1206.4	1206.2	1205.9	1207.4	-----	-----	-----
Water Temperature (C)	0.1	35	20.1	21.3	10.2	24.6	27[1,2,6], 29[1,2,6]	0	0%
Dissolved Oxygen (mg/l)	0.1	35	9.3	9.0	5.1	13.3	5[1,7]	0	0%
Dissolved Oxygen (% Sat.)	0.1	35	106.1	104.3	58.9	156.2	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	29	9.9	9.0	7.9	13.3	5[1,7]	0	0%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	6	6.5	6.6	5.1	7.6	5[1,7]	0	0%
Specific Conductance (umho/cm)	1	35	697	707	636	727	2,000[4]	0	0%
pH (S.U.)	0.1	35	8.3	8.4	7.8	8.6	6.5[1,3,7], 9.0[1,3,6], 9.5[5,6]	0	0%
Turbidity (NTUs)	1	28	36	29	12	123	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	35	331	326	274	399	-----	-----	-----
Secchi Depth (in.)	1	4	20	19	16	24	-----	-----	-----
Alkalinity, Total (mg/l)	7	8	156	157	148	162	-----	-----	-----
Ammonia, Total (mg/l)	0.02	8	-----	0.06	n.d.	0.18	3.9 [1,6,9], 0.79[1,8,9]	0	0%
Carbon, Total Organic (mg/l)	0.05	8	4.6	3.2	2.8	9.2	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	8	15	14	6	29	-----	-----	-----
Chloride (mg/l)	1	8	11	12	8	12	175[1,6], 100[1,8], 438[3,6], 250[3,8]	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	26	10.3*	9	4	35	8[10]	20	77%
Chlorophyll *a* (ug/l) – Lab Determined	1	4	32.8*	24	8	76	8[10]	3	75%
Dissolved Solids, Total (mg/l)	5	8	470	463	430	560	1,750[3,6], 1,000[3,8], 3,500[5,6], 2,000[5,8], 500[11]	0, 0, 0, 0, 1	0%, 0%, 0%, 0%, 13%
Iron, Dissolved (ug/l)	40	4	-----	n.d.	n.d.	40	1,000[8]	0	0%
Iron, Total (ug/l)	40	4	865	805	320	1,530	300[11]	4	100%
Manganese, Dissolved (ug/l)	2	4	-----	35	n.d.	90	1,000[8]	0	0%
Manganese, Total (ug/l)	2	4	125	120	40	220	50[11]	2	50%
Nitrogen, Total Kjeldahl (mg/l)	0.1	8	0.8	0.8	0.3	1.5	-----	-----	-----
Nitrogen, Total (mg/l)	0.1	8	0.94*	0.8	0.3	1.8	0.57[10]	14	29%
Nitrate-Nitrite N, Total (mg/l)	0.02	8	-----	n.d.	n.d.	0.50	10[3,6], 100[4,6]	0	0%
Phosphorus, Dissolved (mg/l)	0.01	7	0.04	0.05	n.d.	0.08	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	8	0.090*	0.08	0.05	0.15	0.06[10]	11	23%
Phosphorus-Ortho, Dissolved (mg/l)	0.01	8	-----	0.02	n.d.	0.07	-----	-----	-----
Sulfate (mg/l)	1	8	188	187	172	208	875[3,6], 500[3,8], 250[11]	0	0%
Suspended Solids, Total (mg/l)	4	8	10	9	5	18	158[1,6], 90[1,8]	0	0%
Microcystin, Total (ug/l)	0.2	4	-----	n.d.	n.d.	0.2	-----	-----	-----

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, Oxidation-Reduction Potential, Turbidity, Chlorophyll a (Field Probe), and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.
- (1) Criteria for the protection of Warmwater Permanent Fish Life Propagation Waters (South Dakota) or Class I Warmwater Aquatic Life (Nebraska).
- (2) South Dakota's temperature criterion is 27 C and Nebraska's is 29 C.
- (3) Criteria for the protection of domestic water supply waters.
- (4) Criteria for the protection of agricultural water supply waters.
- (5) Criteria for the protection of commerce and industry waters.
- (6) Daily maximum criterion (monitoring results directly comparable to criterion).
- (7) Daily minimum criterion (monitoring results directly comparable to criterion).
- (8) 30-day average criterion (monitoring results not directly comparable to criterion).
- (9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (10) Nutrient criteria – Gavins Point Reservoir is classified R9 by Nebraska for application of nutrient criteria.
- (11) The criteria for total dissolved solids, iron, and manganese are listed by the State of Nebraska to protect the beneficial use of public drinking water. Where the natural background level is greater than these criteria, the State of Nebraska states that the background level is to be used in place of the criteria. The elevated levels are believed indicative of natural background conditions and are not considered a water quality standards "violation".

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5 C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1 C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5 C occurs over a 1-meter depth increment.

* The highlighted mean values indicate use impairment based on State of Nebraska 2008 Section 303(d) impairment assessment criteria.

Plate 311. Summary of monthly (June through September) water quality conditions monitored in Gavins Point Reservoir near the Devils Nest Area (site GPTLK0822DW) during 2008.

Parameter	Monitoring Results(A)						Water Quality Standards Attainment		
	Detection Limit(B)	No. of Obs.	Mean(C)	Median	Min.	Max.	State WQS Criteria(D)	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	5	1206.5	1206.4	1205.9	1207.4	-----	-----	-----
Water Temperature (C)	0.1	27	19.7	21.8	10.0	23.8	27(1,2,6), 29(1,2,6)	0	0%
Dissolved Oxygen (mg/l)	0.1	27	9.5	8.8	6.2	13.6	5(1,7)	0	0%
Dissolved Oxygen (% Sat.)	0.1	27	107.0	103.9	73.6	138.2	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)(E)	0.1	24	9.7	8.9	8.1	13.6	5(1,7)	0	0%
Hypolimnion Dissolved Oxygen (mg/l)(E)	0.1	3	8.0	7.0	6.2	10.9	5(1,7)	0	0%
Specific Conductance (umho/cm)	1	27	701	708	647	729	-----	-----	-----
pH (S.U.)	0.1	27	8.3	8.3	7.9	8.6	6.5(1,3,7), 9.0(1,3,6), 9.5(5,6)	0	0%
Turbidity (NTUs)	1	20	33	33	11	68	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	27	334	328	276	398	-----	-----	-----
Chlorophyll *a* (ug/l) – Field Probe	1	21	9.8*	10	5	15	8(8)	-----	-----
Secchi Depth (in)	1	4	16	15	12	24	-----	-----	-----

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, Oxidation-Reduction Potential, Turbidity, Chlorophyll a (Field Probe), and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for the protection of Warmwater Permanent Fish Life Propagation Waters (South Dakota) or Class I Warmwater Aquatic Life (Nebraska).
- (2) South Dakota's temperature criterion is 27 C and Nebraska's is 29 C.
- (3) Criteria for the protection of domestic water supply waters.
- (4) Criteria for the protection of agricultural water supply waters.
- (5) Criteria for the protection of commerce and industry waters.
- (6) Daily maximum criterion (monitoring results directly comparable to criterion).
- (7) Daily minimum criterion (monitoring results directly comparable to criterion).
- (8) Nutrient criteria – Gavins Point Reservoir is classified R9 by Nebraska for application of nutrient criteria.

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5 C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1 C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5 C occurs over a 1-meter depth increment.

* The highlighted mean value indicates use impairment based on State of Nebraska 2008 Section 303(d) impairment assessment criteria.

Plate 312. Summary of monthly (May through September) water quality conditions monitored in Gavins Point Reservoir near the Charley Creek Area (Site GPTLK0825DW) during 2008.

Parameter	Monitoring Results[A]						Water Quality Standards Attainment		
	Detection Limit[B]	No. of Obs.	Mean[C]	Median	Min.	Max.	State WQS Criteria[D]	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation (ft-msl)	0.1	5	1206.5	1206.4	1205.9	1207.4	-----	-----	-----
Water Temperature (C)	0.1	18	20.0	21.8	14.0	24.2	27[1,2,6], 29[1,2,6]	0	0%
Dissolved Oxygen (mg/l)	0.1	18	9.8	9.4	8 1	12.2	5[1,7]	0	0%
Dissolved Oxygen (% Sat.)	0.1	18	112.1	110.5	94.8	128.1	-----	-----	-----
Epilimnion/Metalimnion Dissolved Oxygen (mg/l)[E]	0.1	18	9.8	9.4	8 1	12.2	5[1,7]	0	0%
Hypolimnion Dissolved Oxygen (mg/l)[E]	0.1	0[F]	-----	-----	-----	-----	5[1,7]	-----	-----
Specific Conductance (umho/cm)	1	18	691	690	674	712	2,000[4]	0	0%
pH (S.U.)	0.1	18	8.3	8.4	8.0	8.5	6.5[1,3,7], 9.0[1,3,6], 9.5[5,6]	0	0%
Turbidity (NTUs)	1	14	55	57	31	91	-----	-----	-----
Oxidation-Reduction Potential (mV)	1	18	337	335	277	399	-----	-----	-----
Secchi Depth (in.)	1	4	11	11	9	12	-----	-----	-----
Alkalinity, Total (mg/l)	7	4	162	159	157	172	-----	-----	-----
Ammonia, Total (mg/l)	0.02	4	-----	0.05	n.d.	0.09	3.9[1,6,9], 0.77[1,8,9]	0	0%
Carbon, Total Organic (mg/l)	0.05	4	5.2	4.7	3.2	8.3	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	4	14	13	8	23	-----	-----	-----
Chloride (mg/l)	1	4	12	11	11	14	175[1,6], 100[1,8], 438[3,6], 250[3,8]	0	0%
Chlorophyll *a* (ug/l) – Field Probe	1	14	14.0*	13	10	21	8[10]	14	100%
Chlorophyll *a* (ug/l) – Lab Determined	1	4	27.0*	27	9	46	8[10]	4	100%
Dissolved Solids, Total (mg/l)	5	4	449	448	432	468	1,750[3,6], 1,000[3,8], 3,500[5,6], 2,000[5,8], 500[11]	0	0%
Nitrogen, Total Kjeldahl (mg/l)	0.1	4	1.0	1.0	0.6	1.4	-----	-----	-----
Nitrogen, Total (mg/l)	0.1	1	1.05*	1.0	0.6	1.5	0 57[10]	4	100%
Nitrate-Nitrite N, Total (mg/l)	0.02	4	-----	0.08	n.d.	0.15	10[3,6], 100[4,6]	0	0%
Phosphorus, Dissolved (mg/l)	0.01	3	0.04	0.04	0.02	0.06	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	4	0.105*	0.09	0.08	0.16	0.06[10]	4	100%
Phosphorus-Ortho, Dissolved (mg/l)	0.01	4	-----	n.d.	n.d.	0.05	-----	-----	-----
Sulfate (mg/l)	1	4	185	185	175	194	875[3,6], 500[3,8], 250[11]	0	0%
Suspended Solids, Total (mg/l)	4	4	25	16	19	28	158[1,6], 90[1,8]	0	0%
Microcystin, Total (ug/l)	0.2	4	-----	n.d.	n.d.	n.d.	-----	-----	-----

n.d. = Not detected.

(A) Results for water temperature, dissolved oxygen, specific conductance, pH, turbidity, ORP, and chlorophyll *a* (field probe) are for water column depth-profile measurements. Results for chlorophyll *a* (lab determined) and microcystin are for "grab samples" collected at a near-surface depth. Results for other parameters are for "grab samples" collected at near-surface and near-bottom depths.

(B) Detection limits given for the parameters Pool Elevation, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, Oxidation-Reduction Potential, Turbidity, Chlorophyll a (Field Probe), and Secchi Depth are resolution limits for field measured parameters.

(C) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(D) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for the protection of Warmwater Permanent Fish Life Propagation Waters (South Dakota) or Class I Warmwater Aquatic Life (Nebraska).
- (2) South Dakota's temperature criterion is 27 C and Nebraska's is 29 C.
- (3) Criteria for the protection of domestic water supply waters.
- (4) Criteria for the protection of agricultural water supply waters.
- (5) Criteria for the protection of commerce and industry waters.
- (6) Daily maximum criterion (monitoring results directly comparable to criterion).
- (7) Daily minimum criterion (monitoring results directly comparable to criterion).
- (8) 30-day average criterion (monitoring results not directly comparable to criterion).
- (9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (10) Nutrient criteria – Gavins Point Reservoir is classified R9 by Nebraska for application of nutrient criteria.
- (11) The criteria for total dissolved solids, iron, and manganese are listed by the State of Nebraska to protect the beneficial use of public drinking water. Where the natural background level is greater than these criteria, the State of Nebraska states that the background level is to be used in place of the criteria. The elevated levels are believed indicative of natural background conditions and are not considered a water quality standards "violation".

(E) A hypolimnion is defined to occur when a measured depth-profile of water temperature indicates at least a 5 C difference between surface and bottom temperature, or at some point in the measured profile there is at least at 1 C drop in temperature over a 1-meter increment. The top of the hypolimnion is delineated as the lowest depth where a temperature drop of at least 0.5 C occurs over a 1-meter depth increment.

(F) Depth-profiles did not indicate the presence of a hypolimnion during monitored period. It is assumed that the water column experienced complete mixing due to shallower water depths during the monitored period.

* The highlighted mean values indicate use impairment based on State of Nebraska 2008 Section 303(d) impairment assessment criteria.

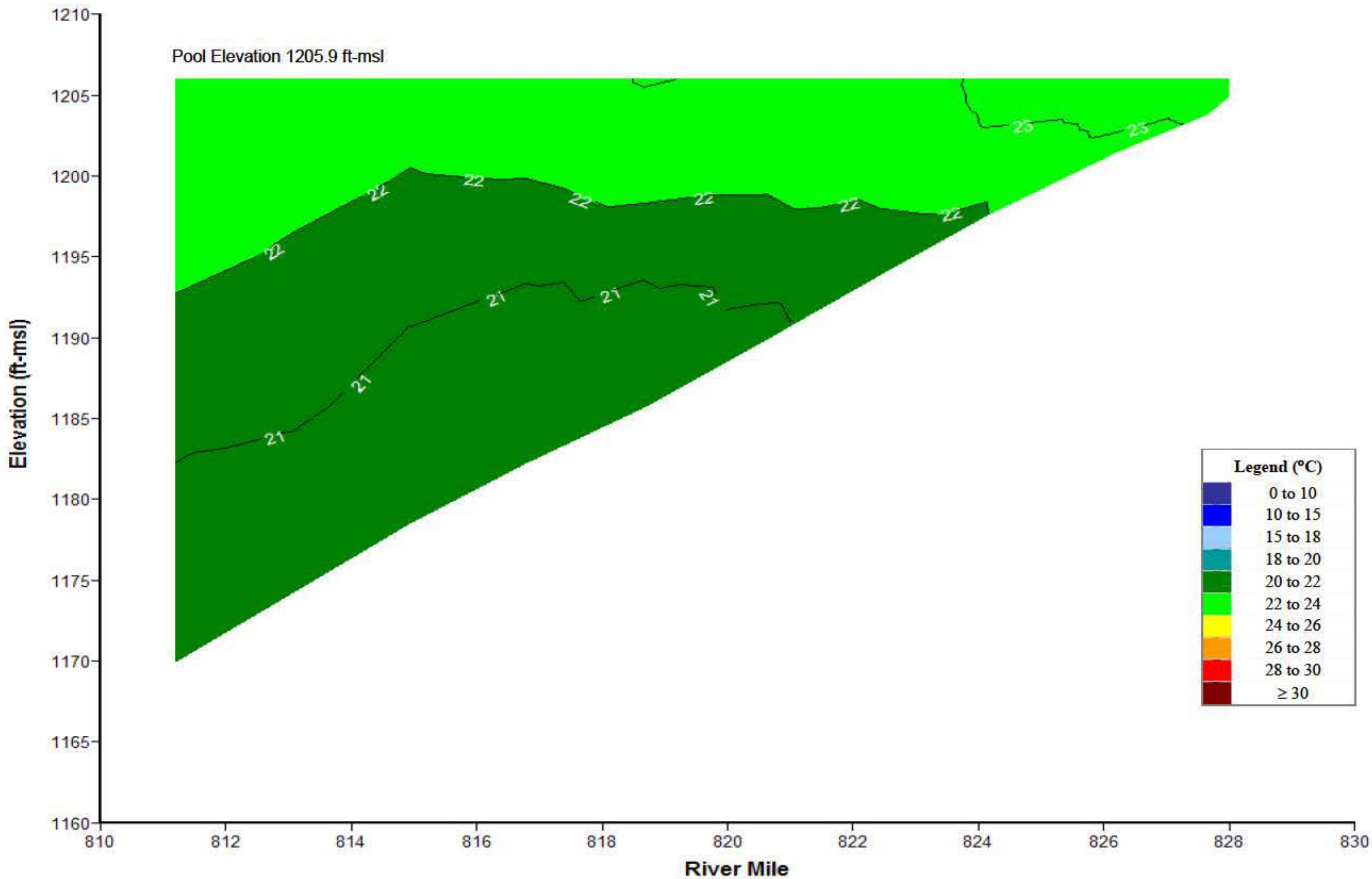


Plate 313. Longitudinal water temperature (°C) contour plot of Gavins Point Reservoir based on depth-profile water temperatures measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on June 17, 2008.

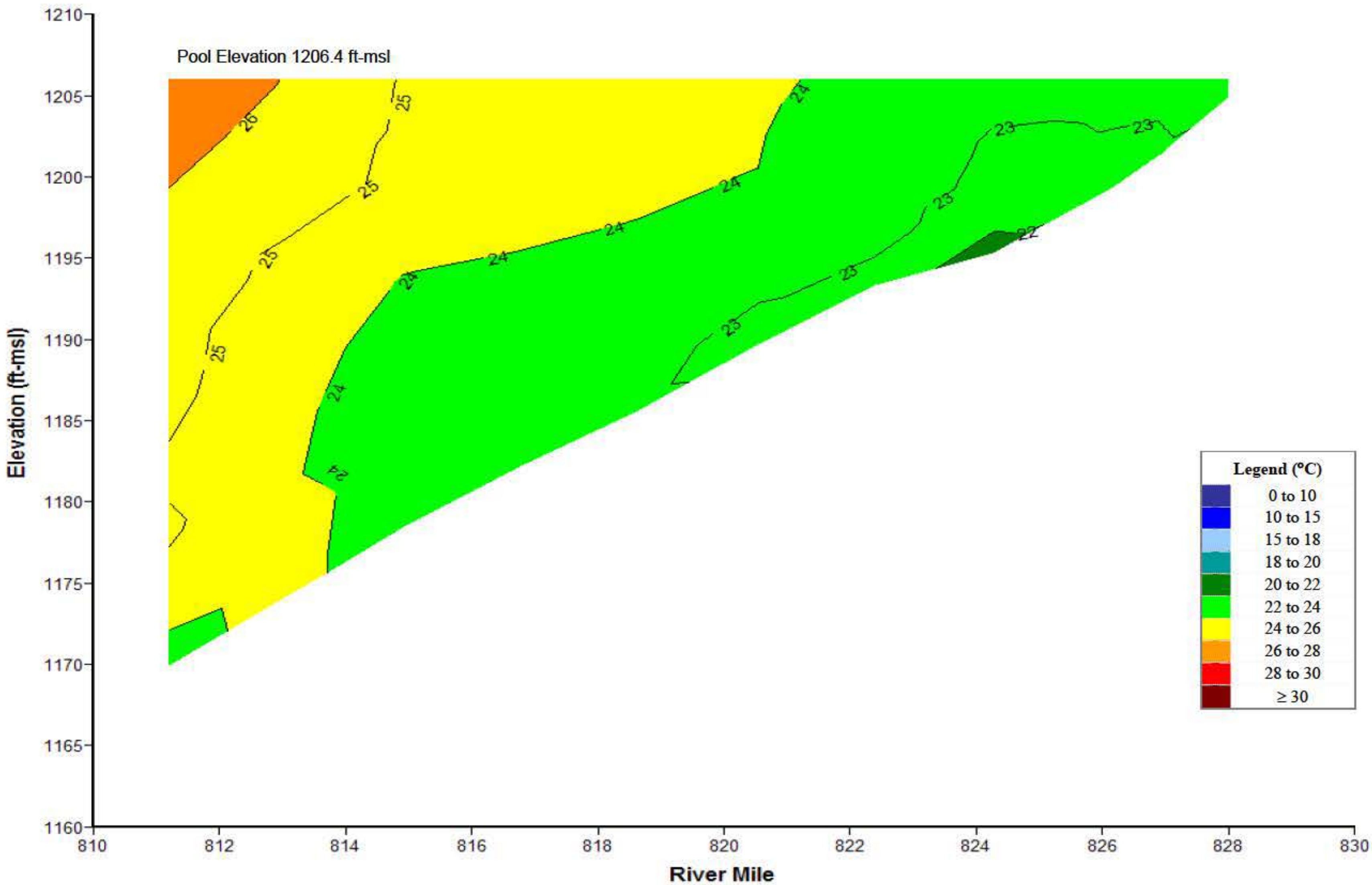


Plate 314. Longitudinal water temperature (°C) contour plot of Gavins Point Reservoir based on depth-profile water temperatures measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on July 14, 2008.

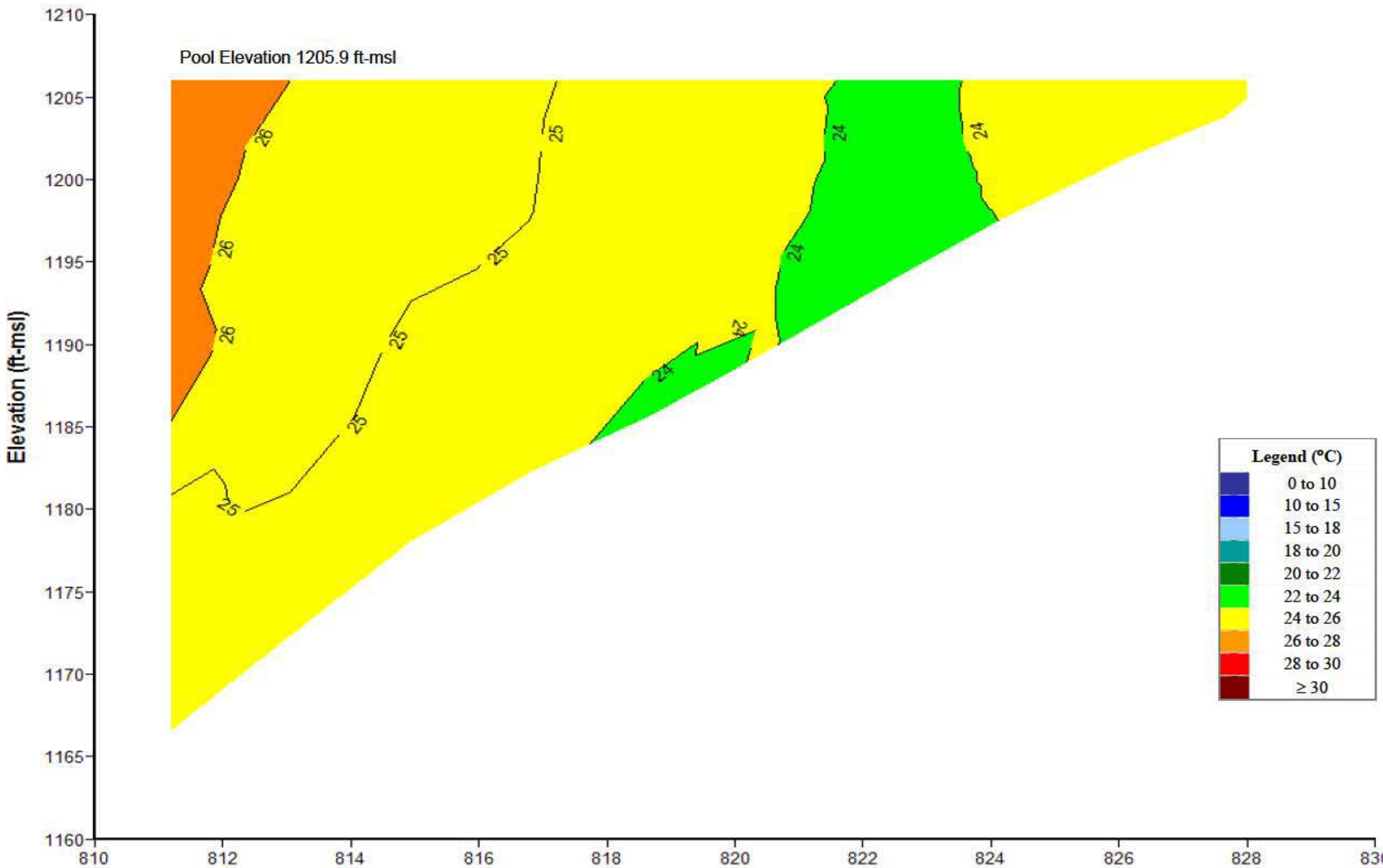


Plate 315. Longitudinal water temperature (°C) contour plot of Gavins Point Reservoir based on depth-profile water temperatures measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on August 11, 2008.

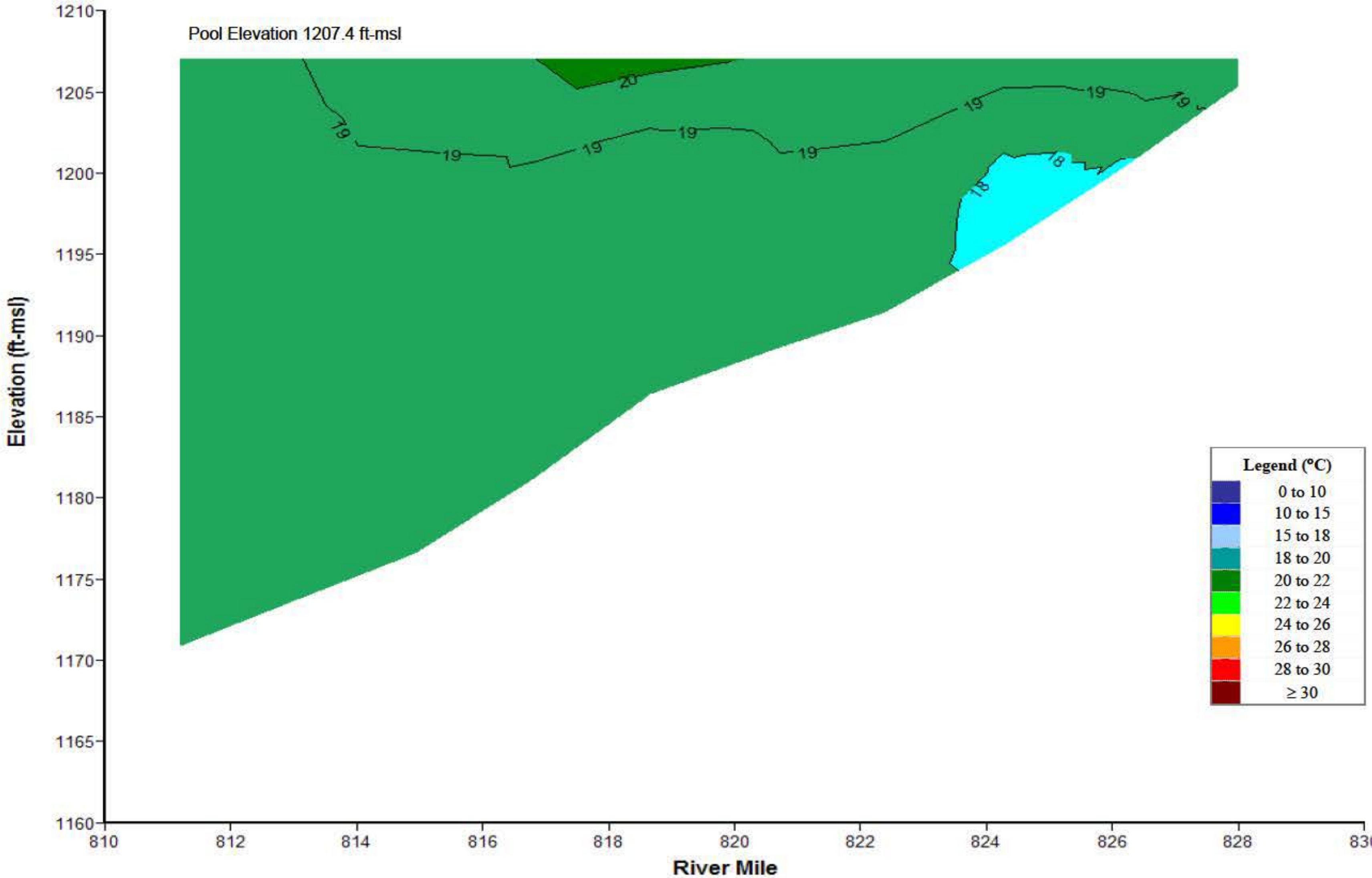


Plate 316. Longitudinal water temperature (°C) contour plot of Gavins Point Reservoir based on depth-profile water temperatures measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on September 15, 2008.

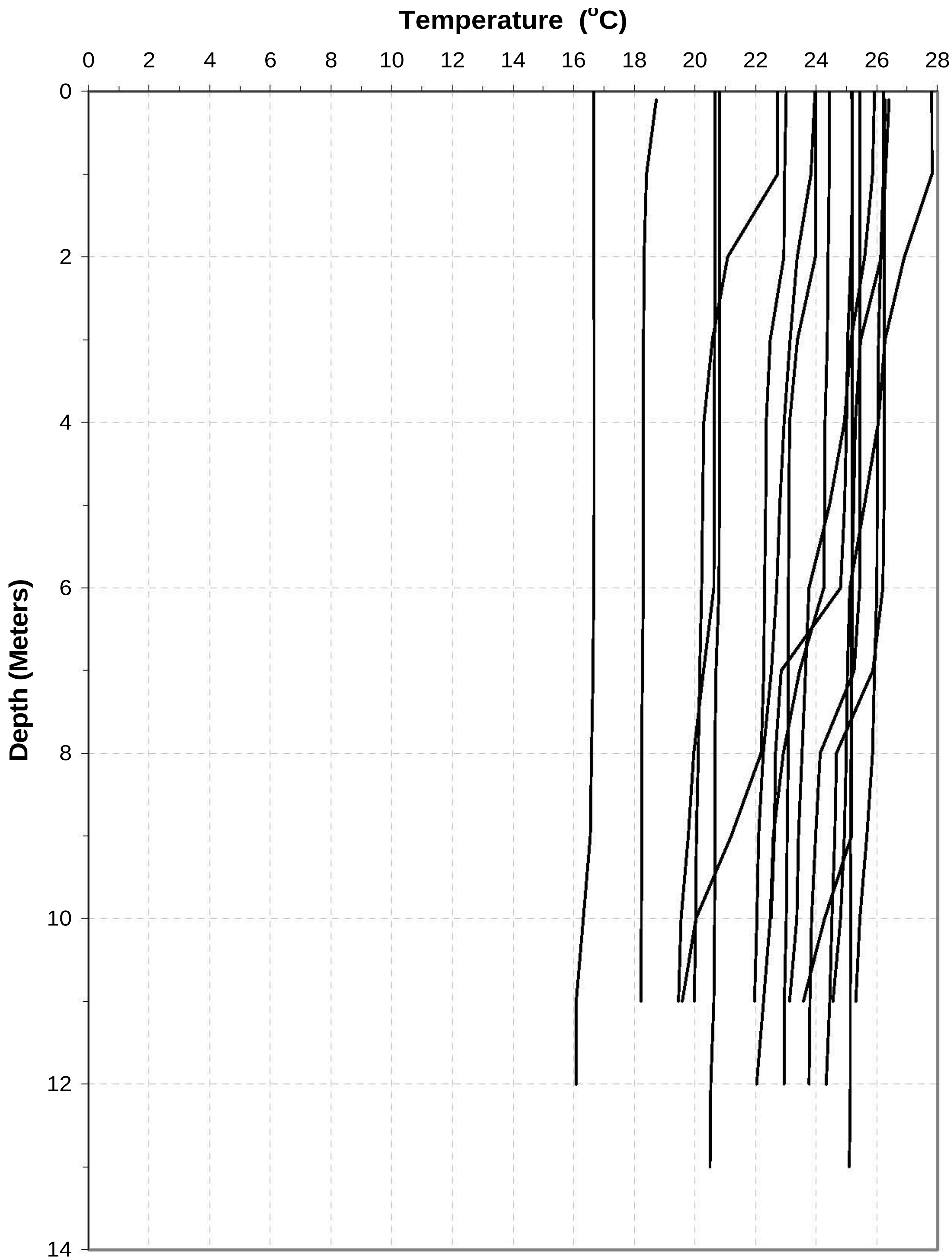


Plate 317. Temperature depth profiles for Gavins Point Reservoir generated from data collected at the near-dam, deepwater ambient monitoring site (i.e., site GPTLK0811A) during the summer months over the 5-year period 2004 to 2008.

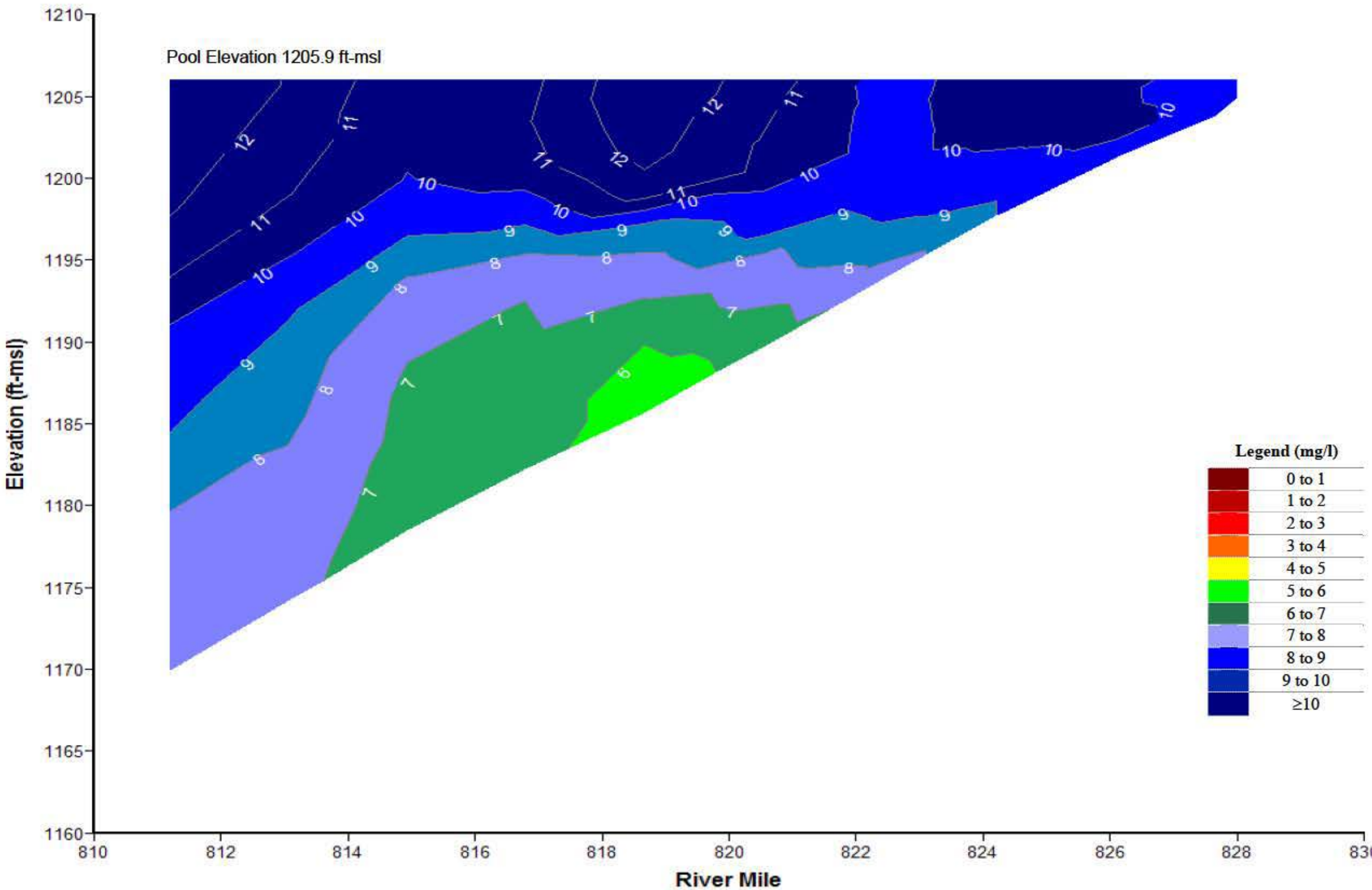


Plate 318. Longitudinal dissolved oxygen (mg/l) contour plot of Gavins Point Reservoir based on depth-profile dissolved oxygen concentrations measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on June 17, 2008.

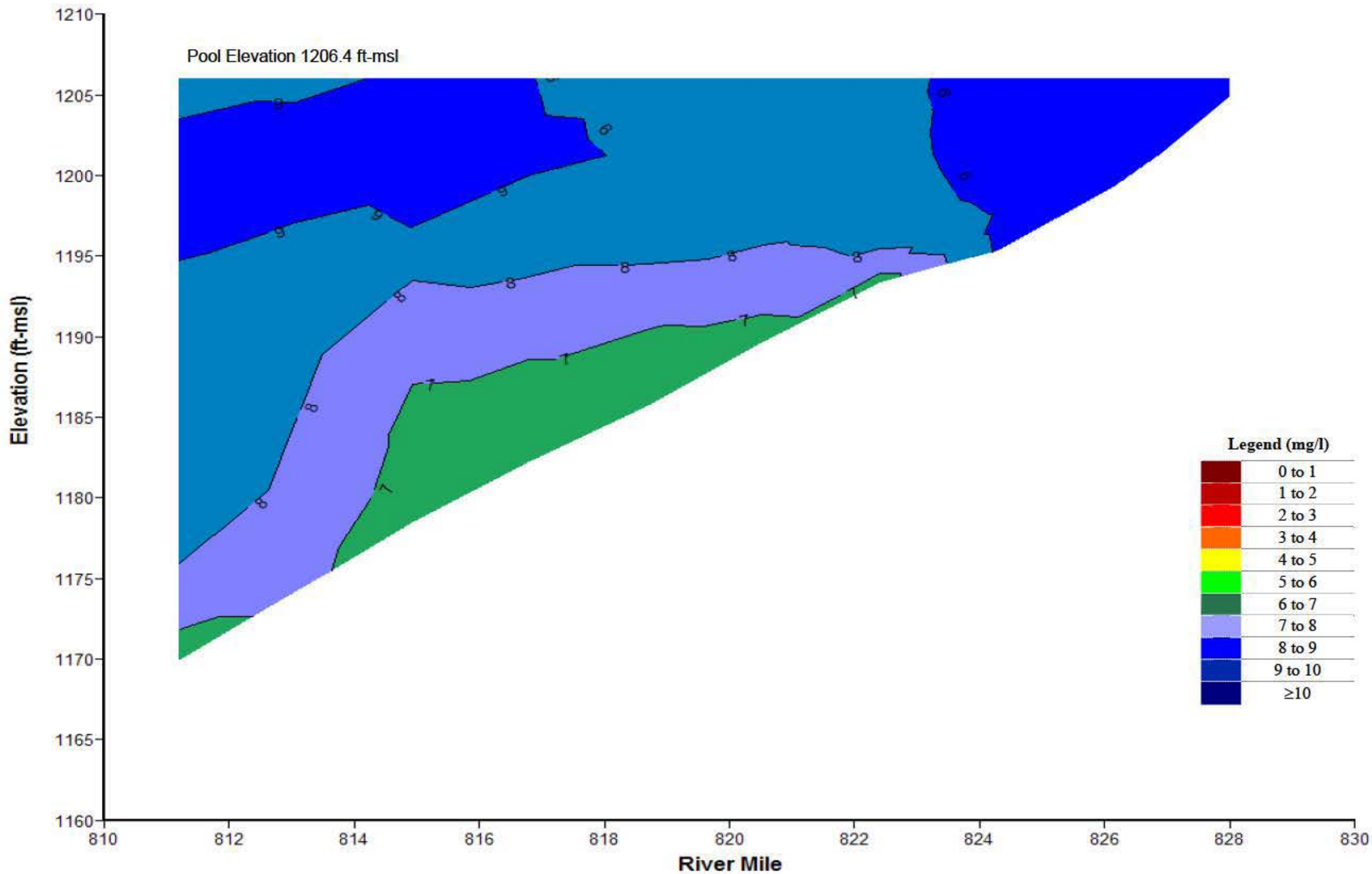


Plate 319. Longitudinal dissolved oxygen (mg/l) contour plot of Gavins Point Reservoir based on depth-profile dissolved oxygen concentrations measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on July 14, 2008.

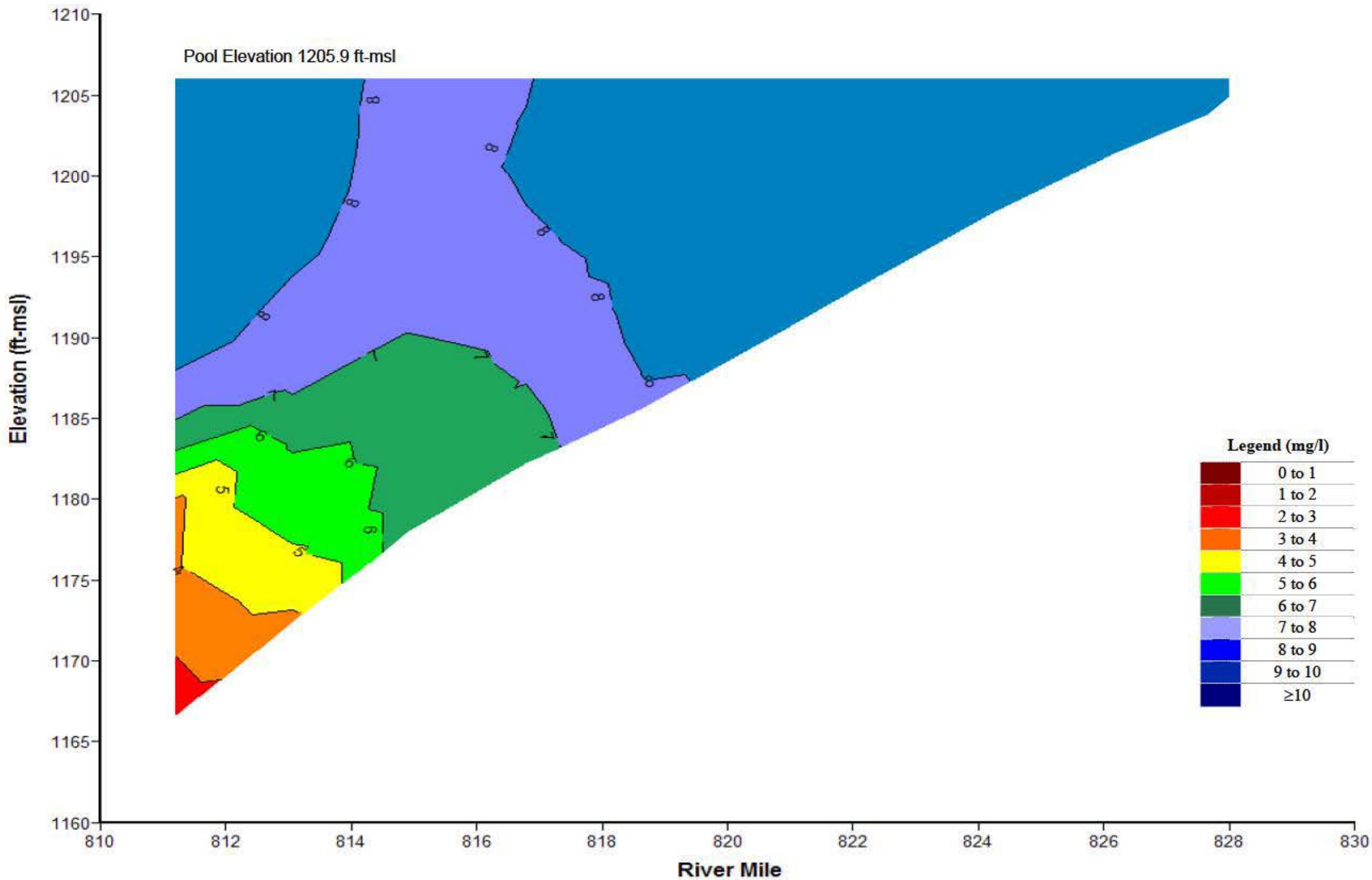


Plate 320. Longitudinal dissolved oxygen (mg/l) contour plot of Gavins Point Reservoir based on depth-profile dissolved oxygen concentrations measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on August 11, 2008.

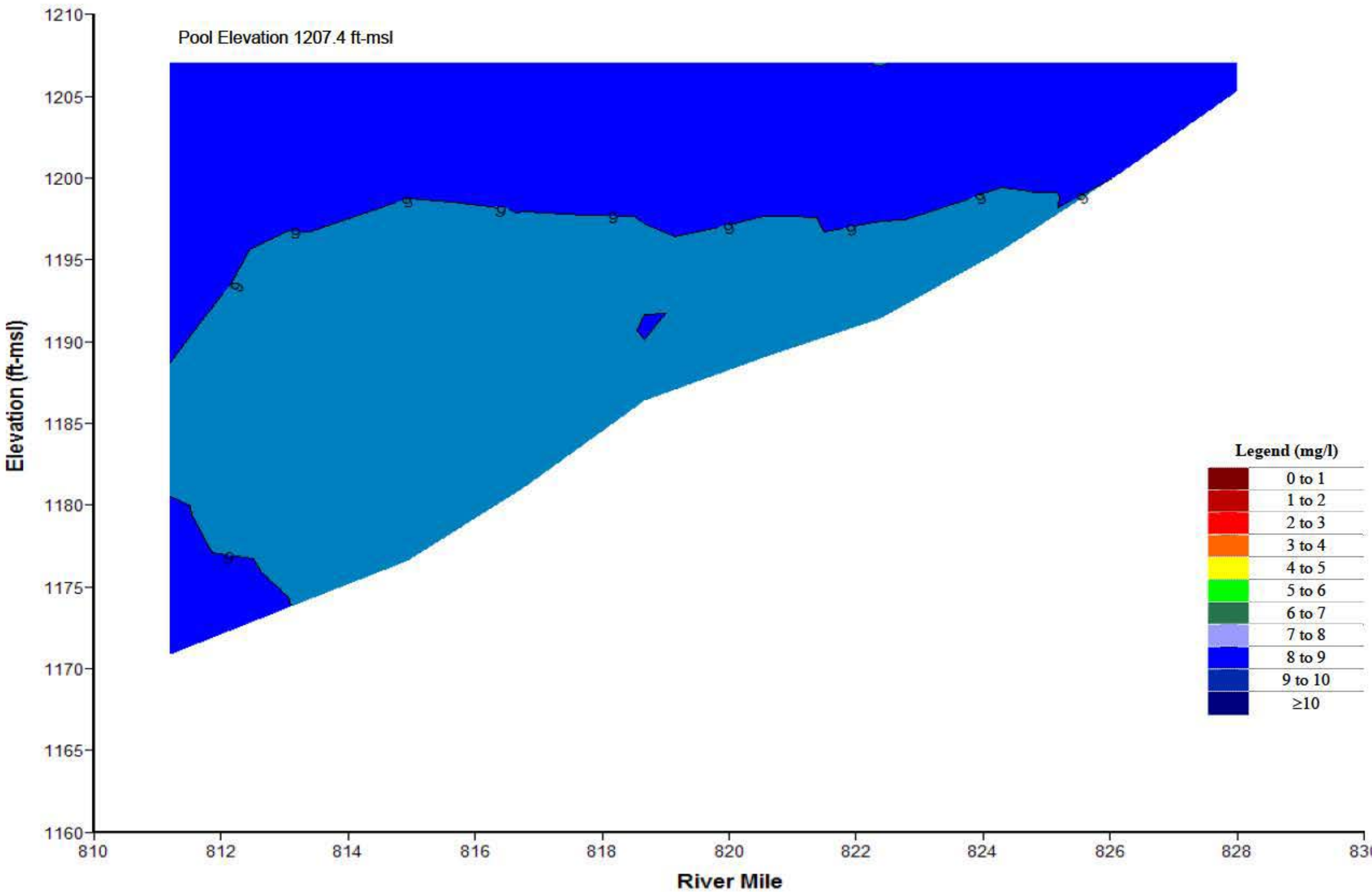


Plate 321. Longitudinal dissolved oxygen (mg/l) contour plot of Gavins Point Reservoir based on depth-profile dissolved oxygen concentrations measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on September 15, 2008.

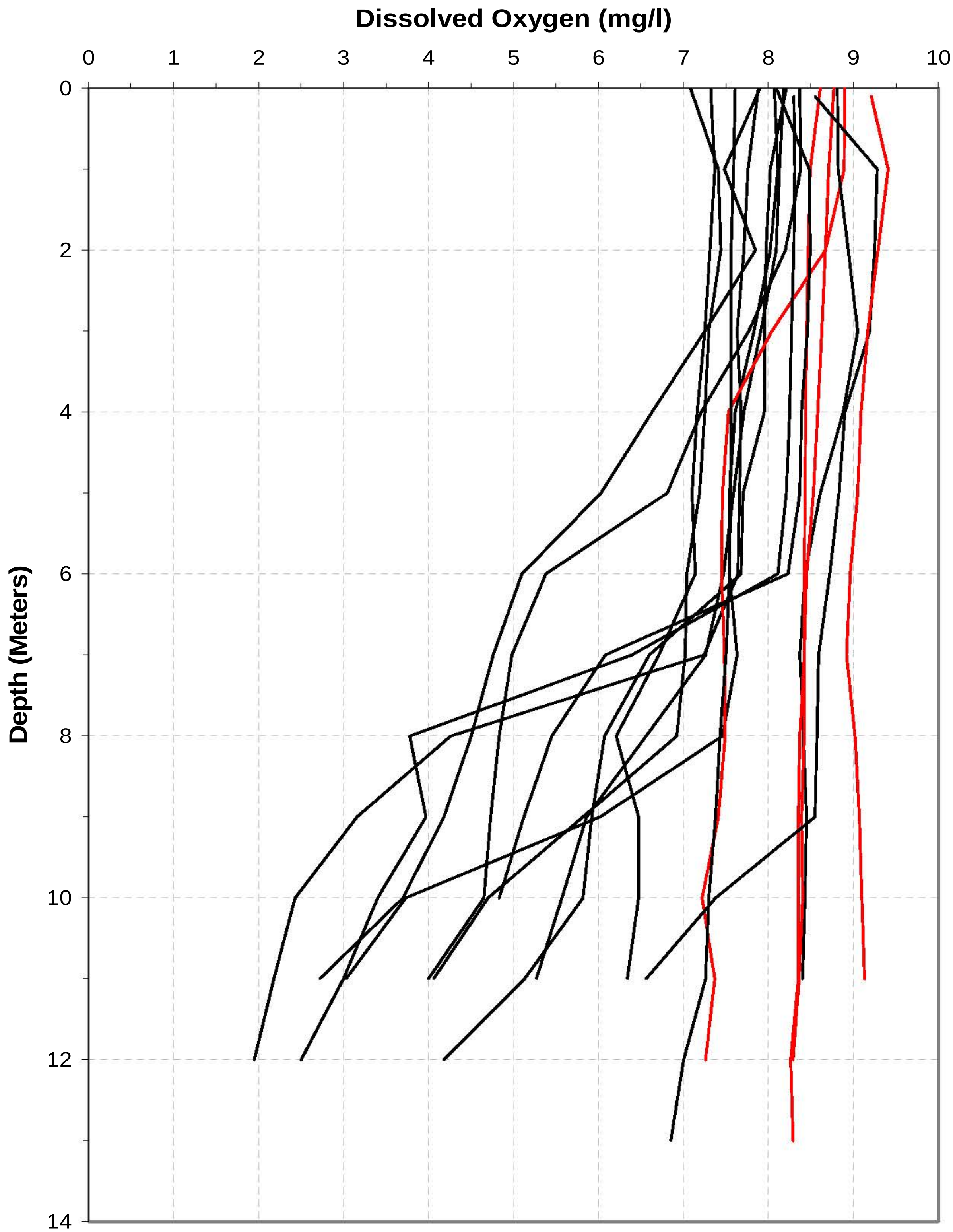


Plate 322. Dissolved oxygen depth profiles for Gavins Point Reservoir generated from data collected at the near-dam, deepwater ambient monitoring site (i.e., site GPTLK0811A) during the summer months over the 5-year period 2004 to 2008.
(Note: Red profile plots were measured in the month of September.)

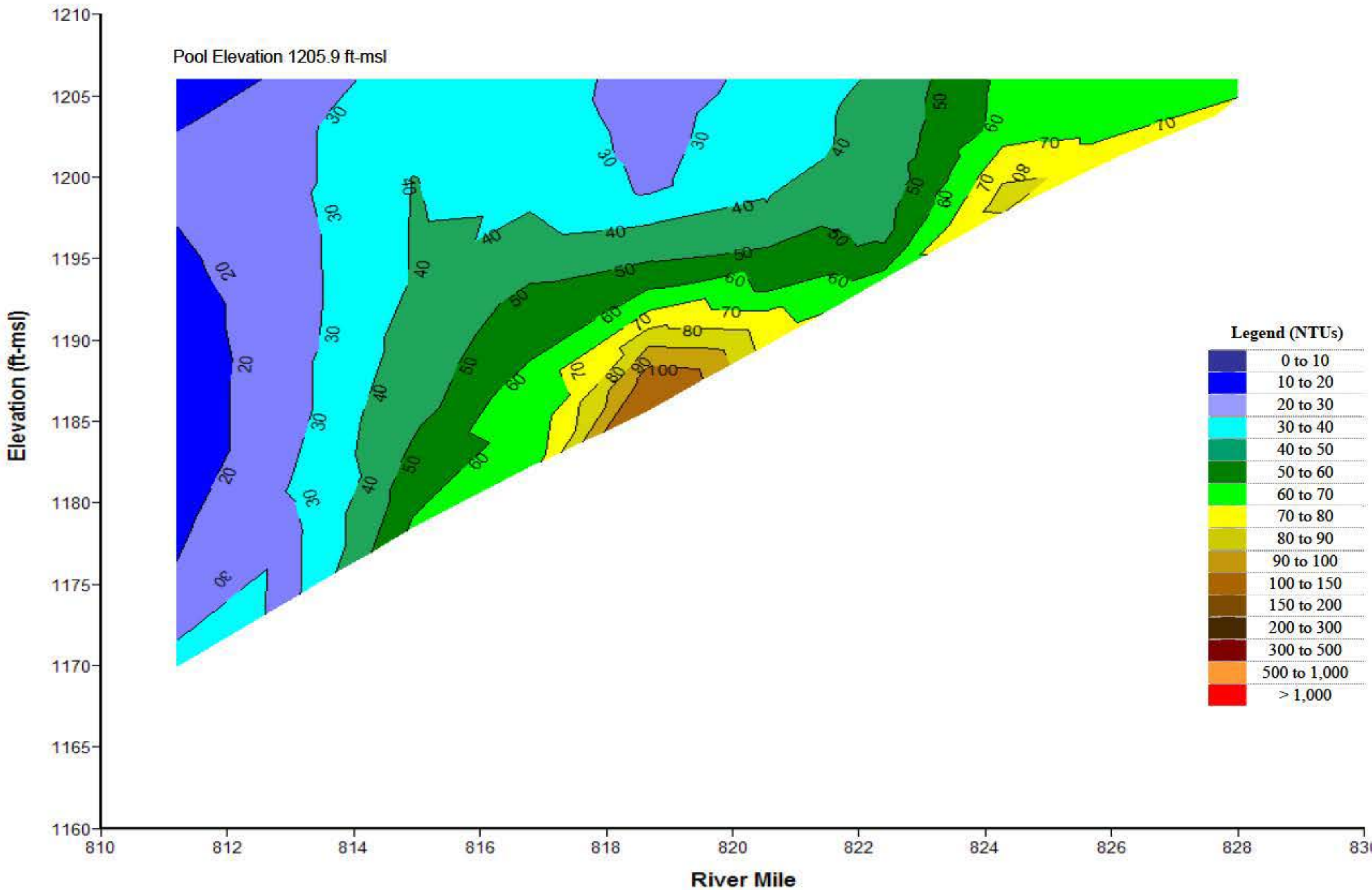


Plate 323. Longitudinal turbidity (NTUs) contour plot of Gavins Point Reservoir based on depth-profile turbidity levels measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on June 17, 2008.

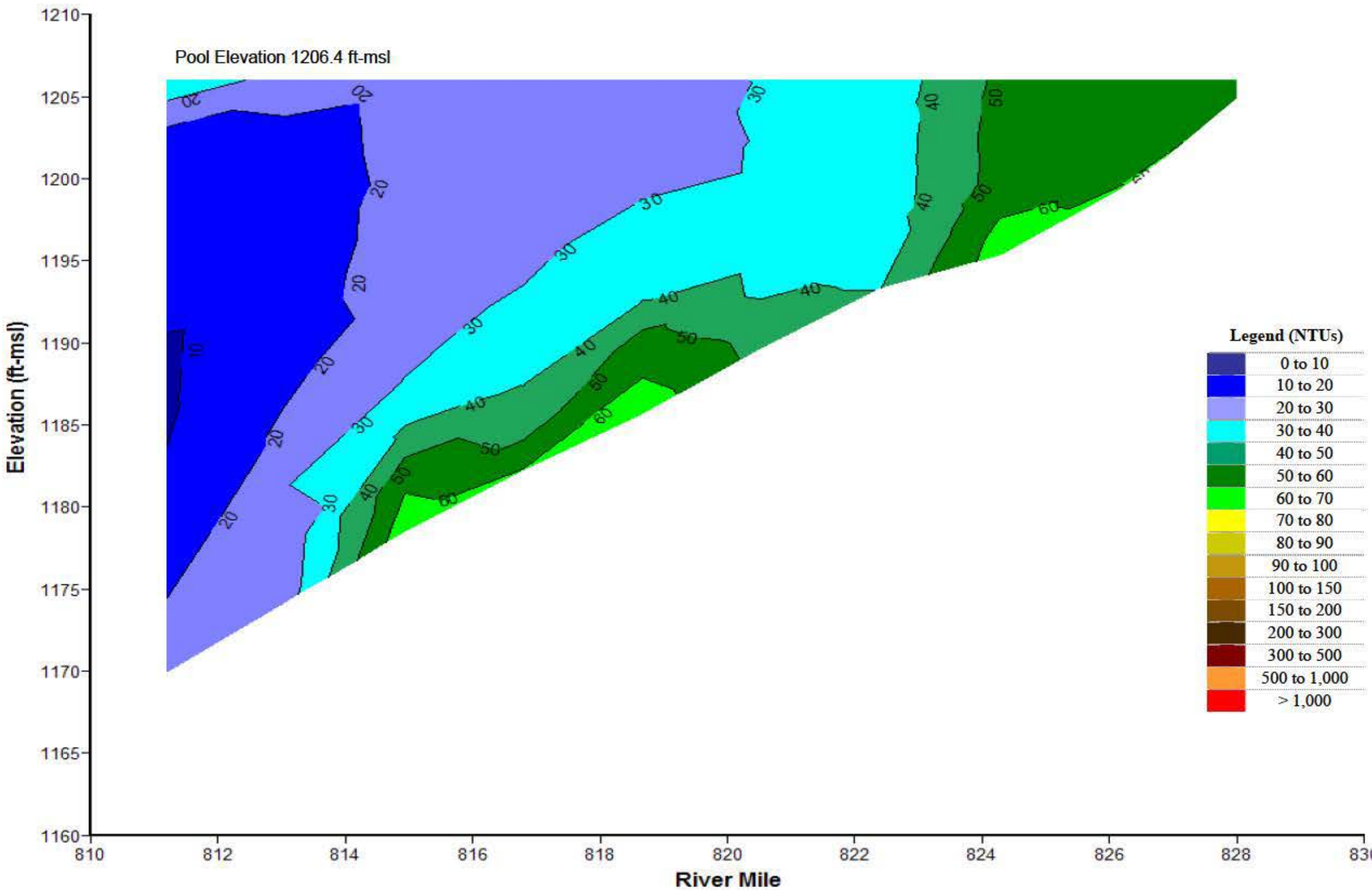


Plate 324. Longitudinal turbidity (NTUs) contour plot of Gavins Point Reservoir based on depth-profile turbidity levels measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on July 14, 2008.

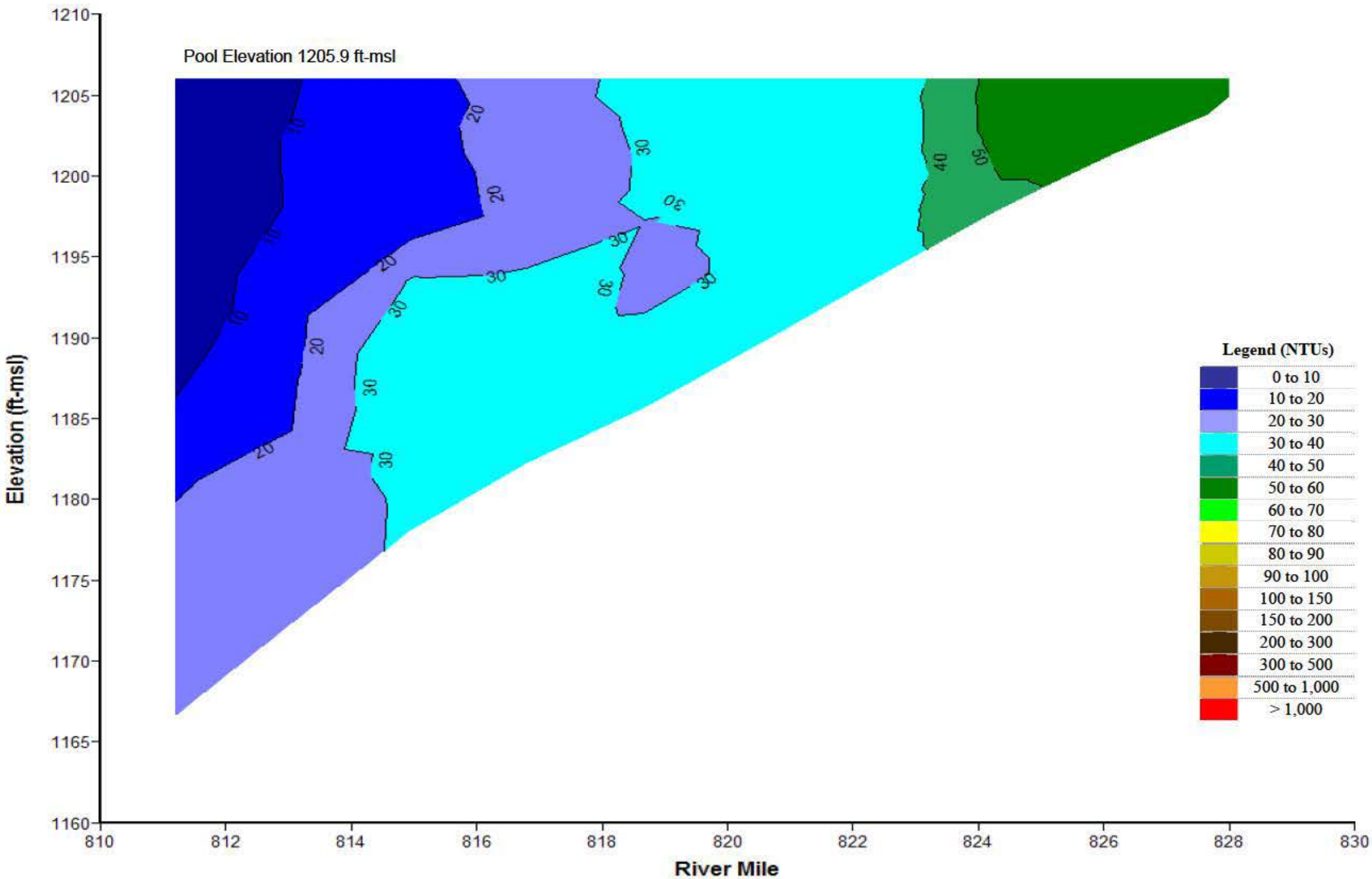


Plate 325. Longitudinal turbidity (NTUs) contour plot of Gavins Point Reservoir based on depth-profile turbidity levels measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on August 11, 2008.

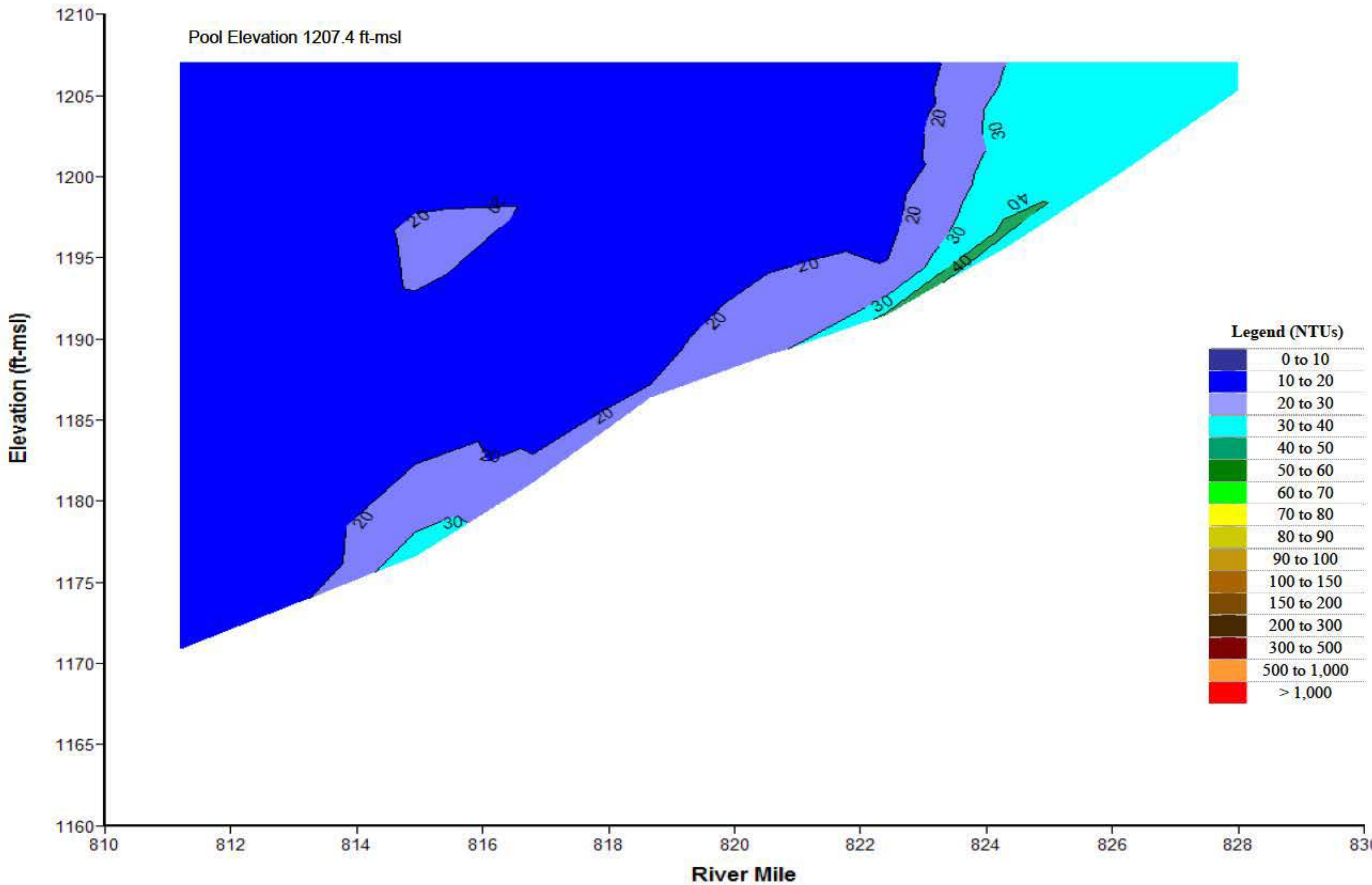


Plate 326. Longitudinal turbidity (NTUs) contour plot of Gavins Point Reservoir based on depth-profile turbidity levels measured at sites GPTLK0811A, GPTLK0815DW, GPTLK0819DW, GPTLK0822DW, and GPTLK0825DW on September 15, 2008.

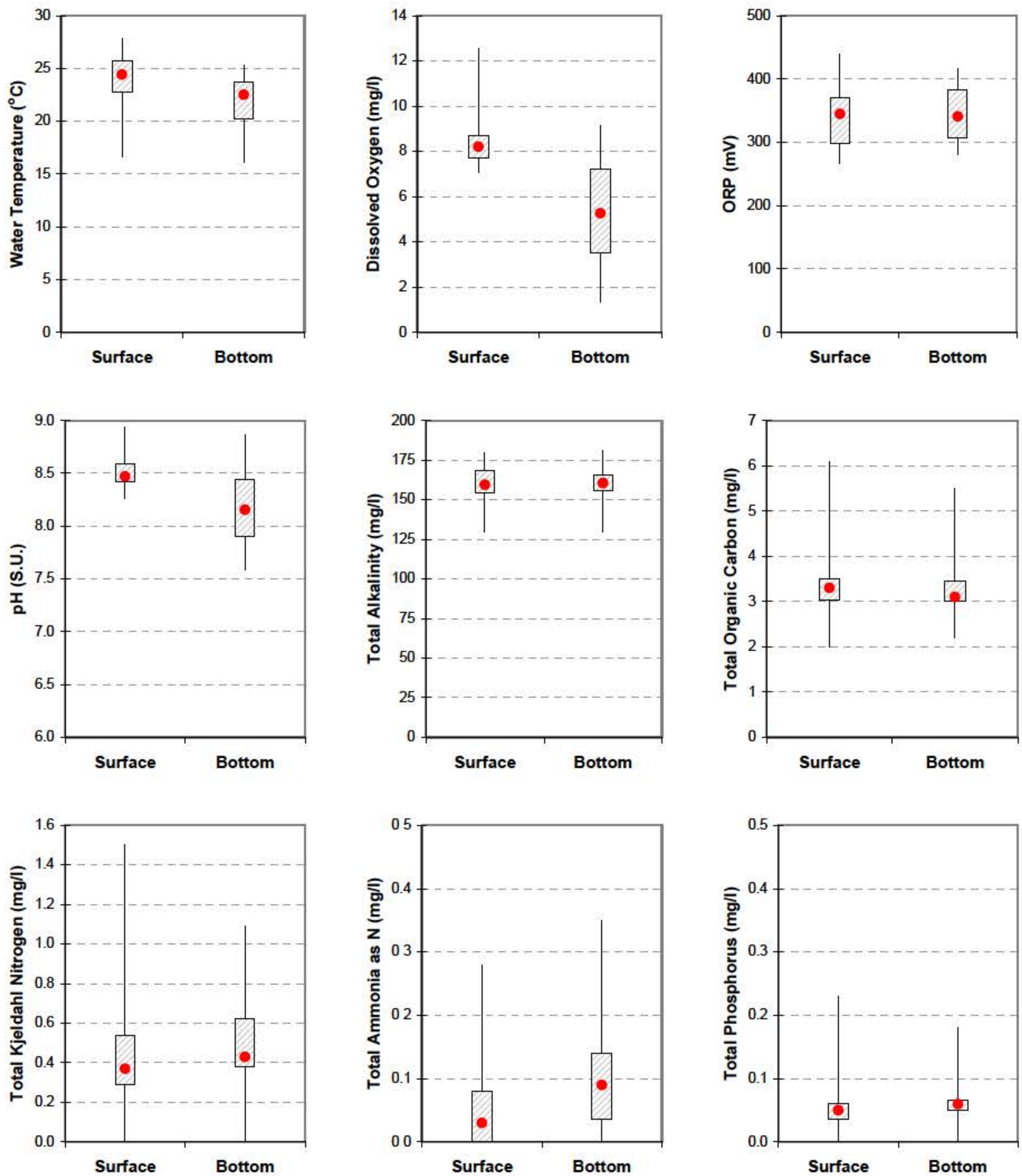


Plate 327. Box plots comparing paired surface and bottom water temperature, dissolved oxygen, oxidation-reduction potential, pH, alkalinity, total organic carbon, total Kjeldahl nitrogen, total ammonia nitrogen, and total phosphorus measurements taken in Gavins Point Reservoir at site GPTLK0811A during the summer months of 2004 through 2008.
(Box plots display minimum, 25th percentile, 75th percentile, and maximum. Median value is indicated by the red dot.)

Plate 328. Total biovolume, number of genera present and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected at the near-dam, deepwater ambient monitoring site (i.e., site GPTLK0811A) at Gavins Point Reservoir during the 5-year period 2004 through 2008.

Date	Total Sample Biovolume (um^3)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta		Shannon-Weaver Genera Diversity
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	
Jun 2004	2,020,993	1	0.38	0	-----	0	-----	2	0.37	2	0.25	0	-----	0	-----	1.49
Jul 2004	1,260,399	0	-----	0	-----	0	-----	1	0.27	2	0.73	0	-----	0	-----	0.68
Aug 2004	428,086,948	7	0.33	3	<0.01	1	0.01	2	0.06	2	<0.01	1	0.61	1	<0.01	1.24
May 2005	170,642,733	6	0.86	3	0.08	0	-----	1	0.05	1	<0.01	0	-----	0	-----	1.29
Jun 2005	75,346,609	3	0.78	3	0.03	0	-----	1	0.15	3	<0.01	1	0.03	0	-----	1.35
Jul 2005	621,134,038	10	0.93	3	0.06	1	<0.01	1	<0.01	3	<0.01	0	-----	0	-----	1.61
Aug 2005	400,199,396	7	0.55	6	0.02	2	0.05	1	0.26	4	0.04	3	0.06	2	0.04	2.28
Sep 2005	337,716,027	11	0.49	10	0.04	0	-----	2	0.37	6	0.03	2	0.06	2	0.01	2.21
May 2006	1,170,506,627	12	0.97	13	0.01	0	-----	1	<0.01	2	<0.01	0	-----	2	0.01	1.19
Jun 2006	280,054,880	10	0.78	17	0.16	2	0.01	1	0.01	0	-----	1	0.03	1	0.01	2.15
Jul 2006	710,790,547	15	0.89	9	0.06	1	<0.01	1	<0.01	1	<0.01	3	0.04	1	0.01	2.01
Aug 2006	528,360,481	13	0.75	11	0.10	1	<0.01	1	<0.01	8	0.11	1	0.01	2	0.02	2.52
Sep 2006	520,570,174	19	0.72	22	0.22	0	-----	1	0.01	4	0.03	0	-----	2	0.02	2.84
May 2007	3,539,604,890	10	0.90	10	0.09	0	-----	1	<0.01	0	-----	0	-----	0	-----	1.32
Jun 2007	1,242,668,868	11	0.83	4	0.11	2	0.03	2	0.02	1	<0.01	1	<0.01	0	-----	1.83
Jul 2007	876,807,100	8	0.92	9	0.05	1	<0.01	1	0.03	0	-----	1	<0.01	0	-----	1.44
Aug 2007	674,471,295	8	0.69	11	0.06	0	-----	2	0.02	4	0.03	2	0.18	1	0.01	2.12
Sep 2007	2,492,800,160	12	0.88	13	0.02	0	-----	1	0.01	5	0.10	1	<0.01	2	<0.01	1.67
May 2008	1,995,694,814	13	1.00	3	<0.01	1	<0.01	1	<0.01	0	-----	0	-----	1	<0.01	1.07
Jun 2008	1,260,870	9	0.70	10	0.17	1	<0.01	1	0.13	1	<0.01	1	<0.01	0	-----	1.68
Jul 2008	1,908,747	23	0.98	12	0.01	3	<0.01	1	<0.01	6	<0.01	1	<0.01	1	<0.01	1.03
Aug 2008	772,197,225	6	0.88	11	0.01	2	<0.01	1	0.08	4	0.02	1	<0.01	2	0.01	1.19
Sep 2008	670,486,456	10	0.92	19	0.02	0	<0.01	2	0.05	4	<0.01	2	<0.01	1	<0.01	1.17
Mean	**761,503,925**	**9.7**	**0.78**	**8.8**	**0.06**	**0.8**	**0.01**	**1.3**	**0.08**	**2.7**	**0.07**	**1.0**	**0.07**	**0.9**	**0.01**	**1.63**

* Mean percent composition represents the mean when taxa of that division are present.

Plate 329. Total biovolume, number of genera present and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected from the middle reaches of Gavins Point Reservoir (i.e., site GPTLK0819DW) during 2008.

Date	Total Sample Biovolume (um^3)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta		Shannon-Weaver Genera Diversity
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	
Jun 2008	2,059,796	10	0.58	15	0.10	2	<0.01	1	0.30	2	0.02	1	<0.01	1	<0.01	1.61
Jul 2008	855,766	10	0.86	15	0.06	1	<0.01	1	0.05	4	<0.01	1	0.01	2	0.01	1.61
Aug 2008	288,837,035	7	0.77	10	0.06	1	<0.01	1	0.15	2	<0.01	1	0.01	1	0.01	2.47
Sep 2008	385,615,085	11	0.92	14	0.05	0	-----	1	<0.01	3	0.01	3	0.02	1	<0.01	1.39
Mean	**169,341,921**	**9.5**	**0.78**	**13.5**	**0.07**	**1.0**	**<0.01**	**1.0**	**0.13**	**2.8**	**0.01**	**1.5**	**0.01**	**1.3**	**0.01**	**1.77**

* Mean percent composition represents the mean when taxa of that division are present.

Plate 330. Total biovolume, number of genera present and percent composition (based on biovolume) by taxonomic division for phytoplankton grab samples collected from the upper reaches of Gavins Point Reservoir (i.e., site GPTLK0825DW) during 2008.

Date	Total Sample Biovolume (um^3)	Bacillariophyta		Chlorophyta		Chrysophyta		Cryptophyta		Cyanobacteria		Pyrrophyta		Euglenophyta		Shannon-Weaver Genera Diversity
		No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	No. of Genera	Percent Comp.	
Jun 2008	766,291	19	0.68	16	0.12	3	0.02	1	0.16	2	<0.01	1	<0.01	1	<0.01	2.20
Jul 2008	361,386	17	0.62	12	0.15	1	<0.01	1	0.23	4	<0.01	0	-----	0	-----	1.86
Aug 2008	113,583,376	13	0.67	5	0.07	0	-----	1	0.24	1	<0.01	0	-----	1	0.02	2.00
Sep 2008	589,971,711	10	0.70	16	0.13	0	-----	2	0.14	4	<0.01	2	0.03	1	<0.01	1.65
Mean	**176,170,691**	**14.8**	**0.67**	**12.3**	**0.12**	**1.0**	**0.01**	**1.3**	**0.19**	**2.8**	**<0.01**	**0.8**	**0.02**	**0.8**	**0.01**	**1.93**

* Mean percent composition represents the mean when taxa of that division are present.

Plate 331. Dominant taxa present in phytoplankton grab samples collected at the near-dam monitoring site (site GPTLK0811A) at Gavins Point Reservoir during the period 2004 through 2007.

Date	Division	Dominant Taxa*	Percent of Total Biovolume
Jun 2004	Bacillariophyta	*Fragilaria spp.*	0.38
	Cryptophyta	*Cryptomonas spp.*	0.20
	Cryptophyta	*Rhodomonas minuta*	0.17
	Cyanobacteria	*Aphanothece spp.*	0.17
Jul 2004	Cyanobacteria	*Aphanocapsa spp.*	0.71
	Cryptophyta	*Rhodomonas minuta*	0.28
August 2004	Pyrrophyta	*Ceratium hirundinella*	0.61
	Bacillariophyta	*Fragilaria crotonensis*	0.23
May 2005	Bacillariophyta	*Fragilaria crotonensis*	0.62
	Bacillariophyta	*Asterionella formossa*	0.19
June 2005	Bacillariophyta	*Aulacoseira granulata*	0.54
	Bacillariophyta	*Stephanodiscus spp.*	0.21
	Cryptophyta	*Rhodomonas minuta*	0.15
July 2006	Bacillariophyta	*Cyclotella spp.*	0.47
	Bacillariophyta	*Fragilaria crotonensis*	0.22
	Bacillariophyta	*Aulacoseira spp.*	0.15
August 2006	Bacillariophyta	*Fragilaria crotonensis*	0.29
	Cryptophyta	*Cryptomonas spp.*	0.19
September 2006	Cryptophyta	*Rhodomonas minuta*	0.35
	Bacillariophyta	*Aulacoseira granulata*	0.19
	Bacillariophyta	*Fragilaria crotonensis*	0.10
May 2006	Bacillariophyta	*Fragilaria crotonensis*	0.42
	Bacillariophyta	*Asterionella formossa*	0.38
June 2006	Bacillariophyta	*Fragilaria crotonensis*	0.42
July 2006	Bacillariophyta	*Aulacoseira spp.*	0.41
	Bacillariophyta	*Fragilaria crotonensis*	0.19
August 2006	Bacillariophyta	*Fragilaria crotonensis*	0.19
	Bacillariophyta	*Aulacoseira granulata*	0.14
September 2006	Bacillariophyta	*Stephanodiscus niagarae*	0.24
	Bacillariophyta	*Aulacoseira granulata*	0.11
May 2007	Bacillariophyta	*Fragilaria capucina*	0.64
June 2007	Bacillariophyta	*Aulacoseira spp.*	0.30
	Bacillariophyta	*Fragilaria capucina*	0.26
	Bacillariophyta	*Stephanodiscus niagarae.*	0.12
July 2007	Bacillariophyta	*Cyclotella spp.*	0.41
	Bacillariophyta	*Stephanodiscus niagarae.*	0.30
	Bacillariophyta	*Aulacoseira spp.*	0.17
August 2007	Bacillariophyta	*Stephanodiscus niagarae.*	0.23
	Bacillariophyta	*Aulacoseira spp.*	0.19
	Pyrrophyta	*Peridinium spp.*	0.13
September 2007	Bacillariophyta	*Stephanodiscus niagarae.*	0.41
	Bacillariophyta	*Fragilaria capucina*	0.26
	Cyanobacteria	*Anabaenopsis circularis*	0.10

Plate 331. (Continued).

Date	Division	Dominant Taxa*	Percent of Total Biovolume
May 2008	Bacillariophyta	*Fragilaria crotonensis*	0.66
	Bacillariophyta	*Aulacoseira granulata*	0.20
June 2008	Bacillariophyta	*Fragilaria crotonensis*	0.29
	Bacillariophyta	*Asterionella formossa*	0.26
	Chlorophyta	*Chlamydomonas spp.*	0.15
	Bacillariophyta	*Aulacoseira granulata*	0.14
	Cryptophyta	*Rhodomonas spp.*	0.13
July 2008	Bacillariophyta	*Aulacoseira granulata*	0.48
	Bacillariophyta	*Fragilaria crotonensis.*	0.46
August 2008	Bacillariophyta	*Aulacoseira granulata*	0.65
	Bacillariophyta	*Stephanodiscus spp.*	0.11
	Bacillariophyta	*Synedra spp.*	0.11
September 2008	Bacillariophyta	*Aulacoseira granulata*	0.65
	Bacillariophyta	*Fragilaria crotonensis.*	0.19

* Dominant taxa are genera or species (depending on identification level) that comprised more than 10% of the total sample biovolume.

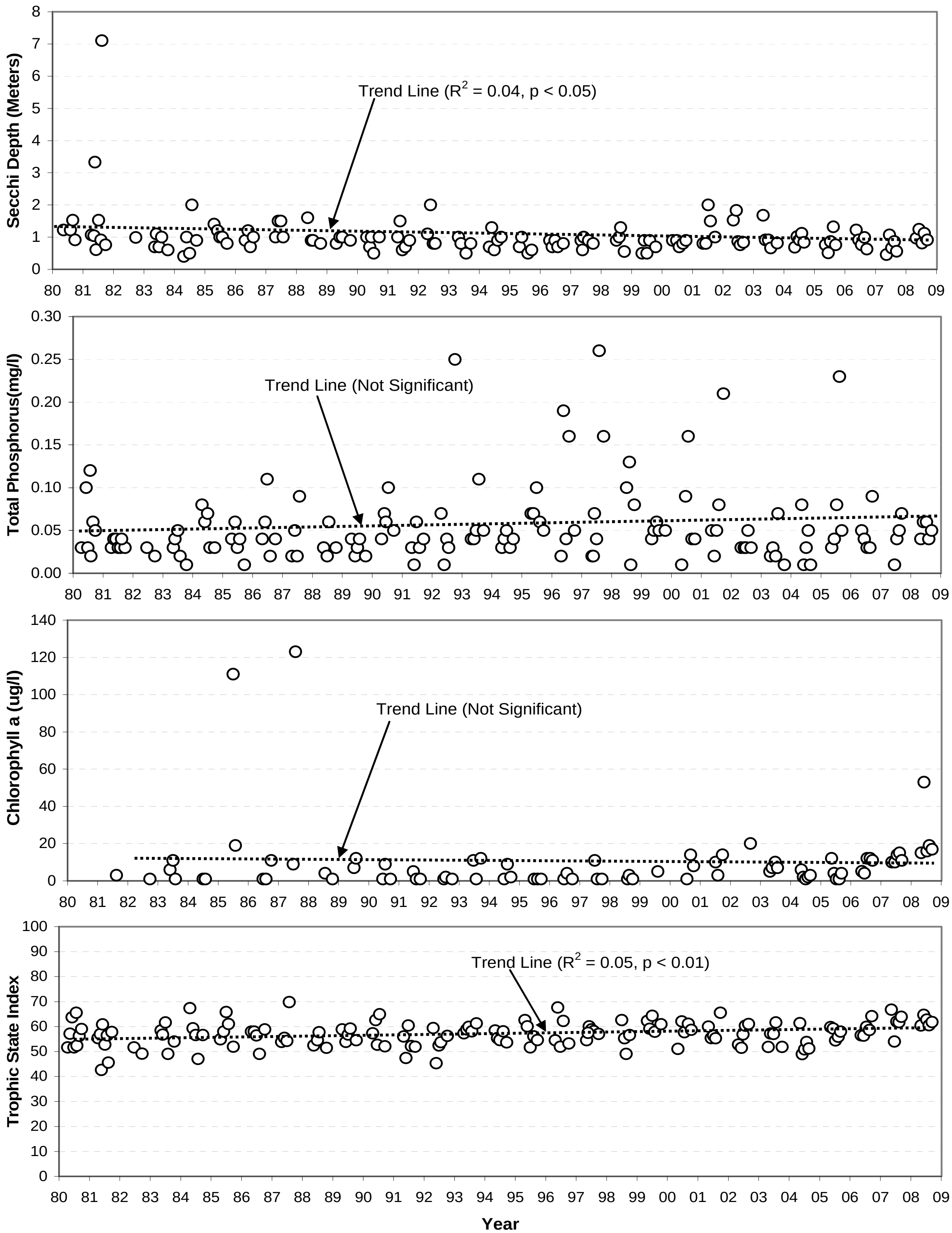


Plate 332. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and Trophic State Index (TSI) monitored in Gavins Point Reservoir at the near-dam, ambient site (i.e., site GTPLK0811A) over the 29-year period of 1980 through 2008.

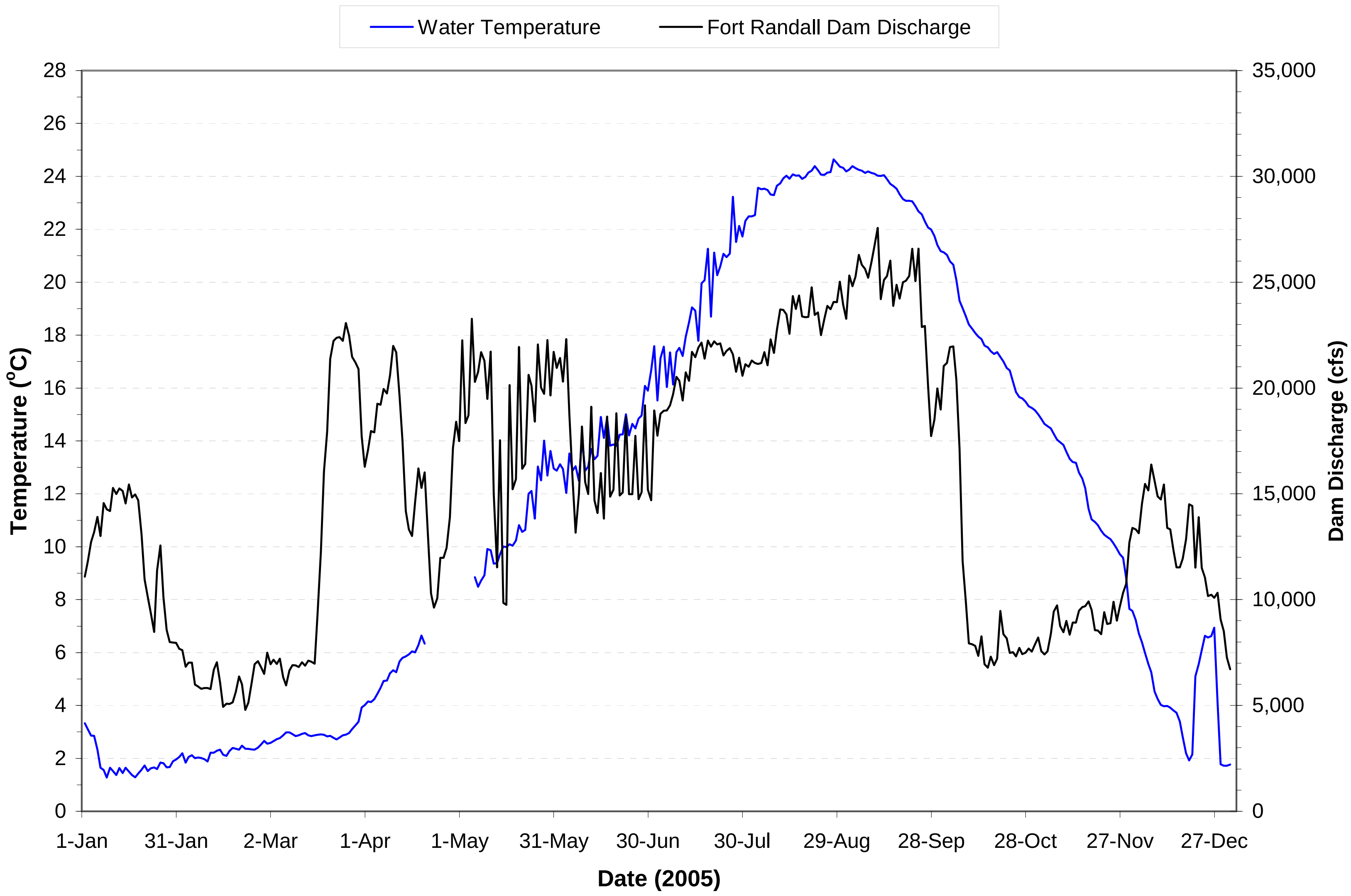


Plate 333. Mean daily water temperature and discharge of the Missouri River at Fort Randall Dam (i.e., site FTRPP1) for 2005. Mean daily temperatures and discharges based on hourly measurements recorded on discharge through Fort Randall Dam.
Note: Gaps in temperature plot are periods when monitoring equipment was not operational.

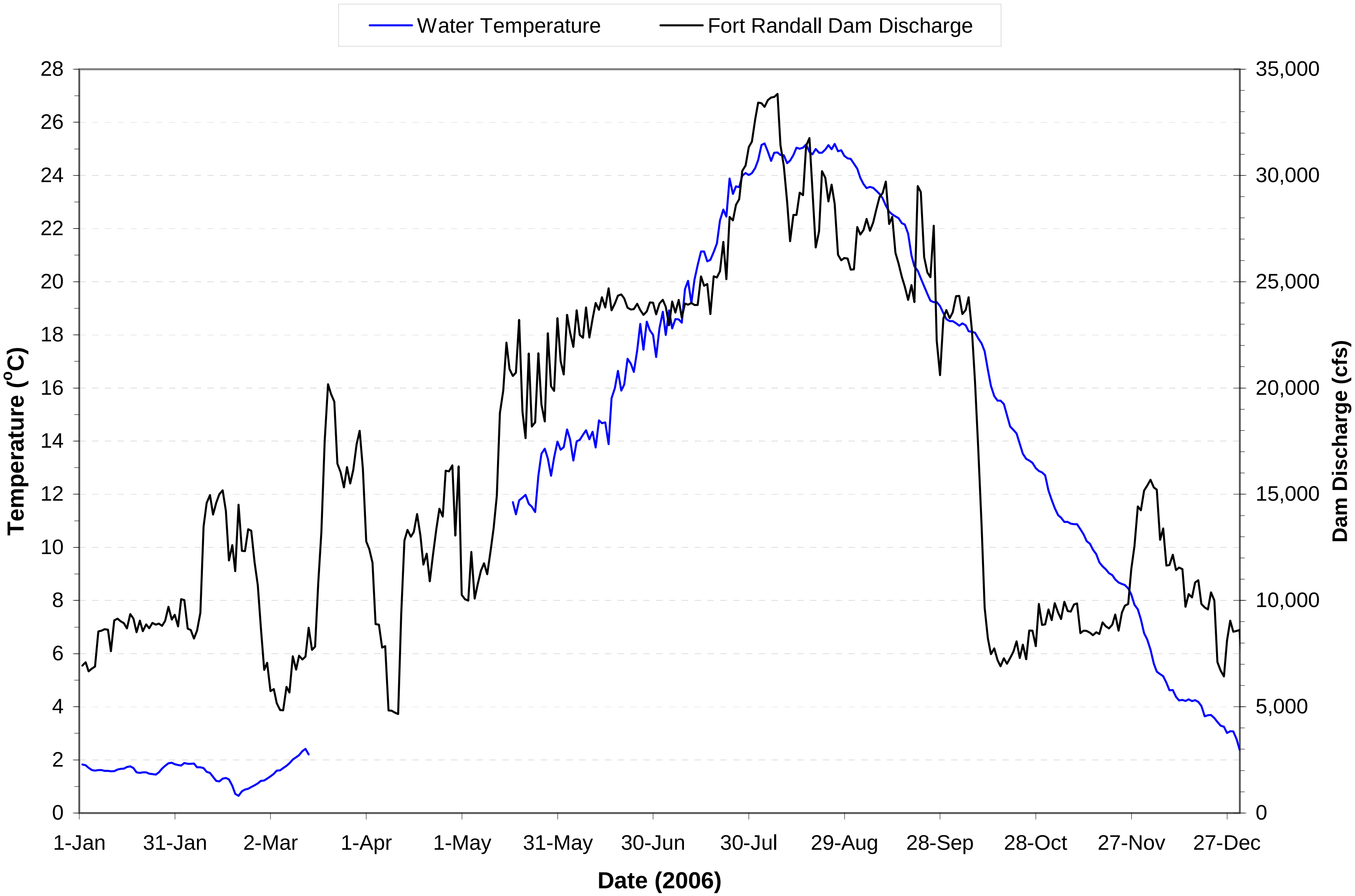


Plate 334. Mean daily water temperature and discharge of the Missouri River at Fort Randall Dam (i.e., site FTRPP1) for 2006. Mean daily temperatures and discharges based on hourly measurements recorded on discharge through Fort Randall Dam.
Note: Gaps in temperature plot are periods when monitoring equipment was not operational.

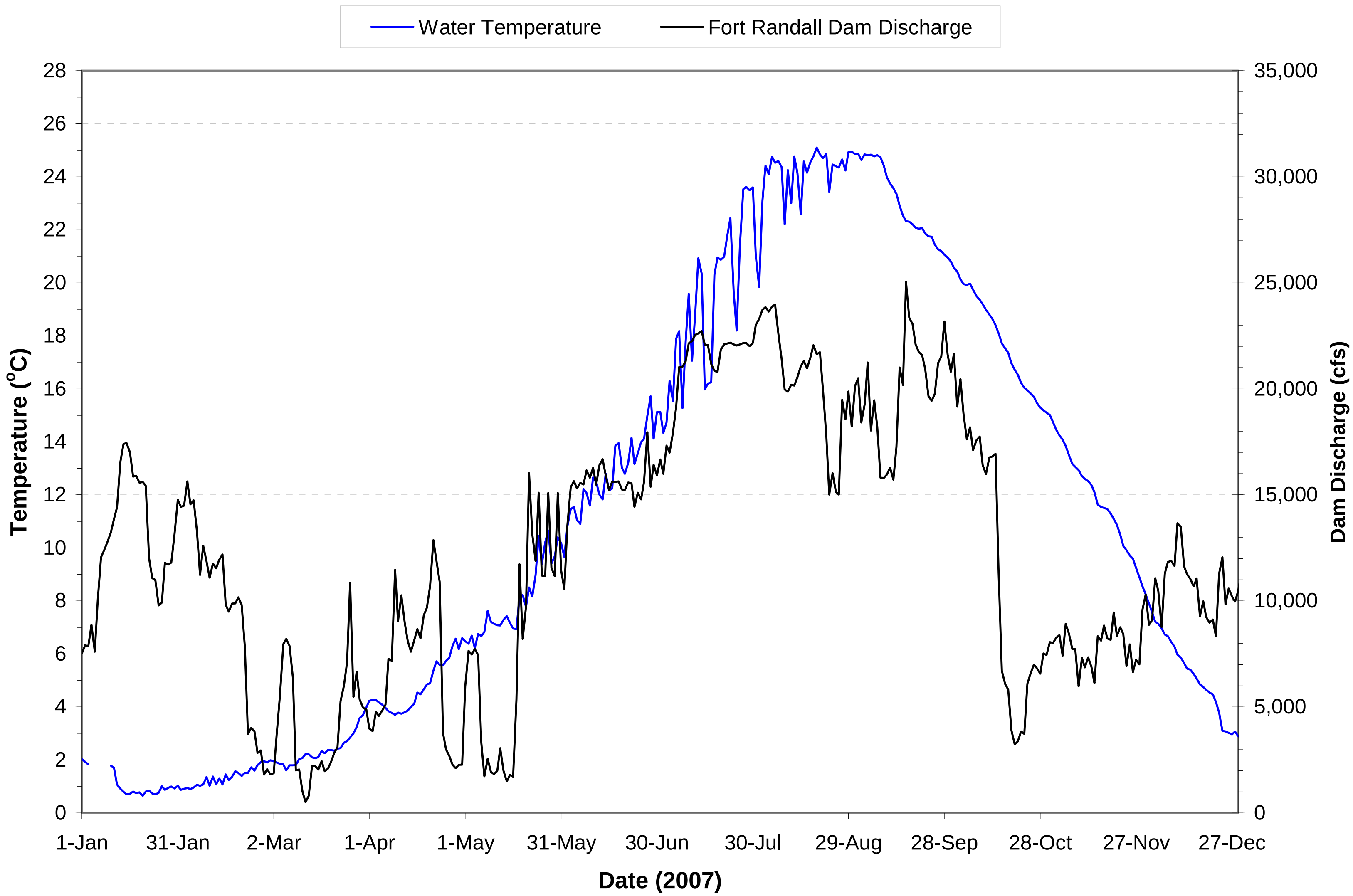


Plate 335. Mean daily water temperature and discharge of the Missouri River at Fort Randall Dam (i.e., site FTRPP1) for 2007. Mean daily temperatures and discharges based on hourly measurements recorded on discharge through Fort Randall Dam.

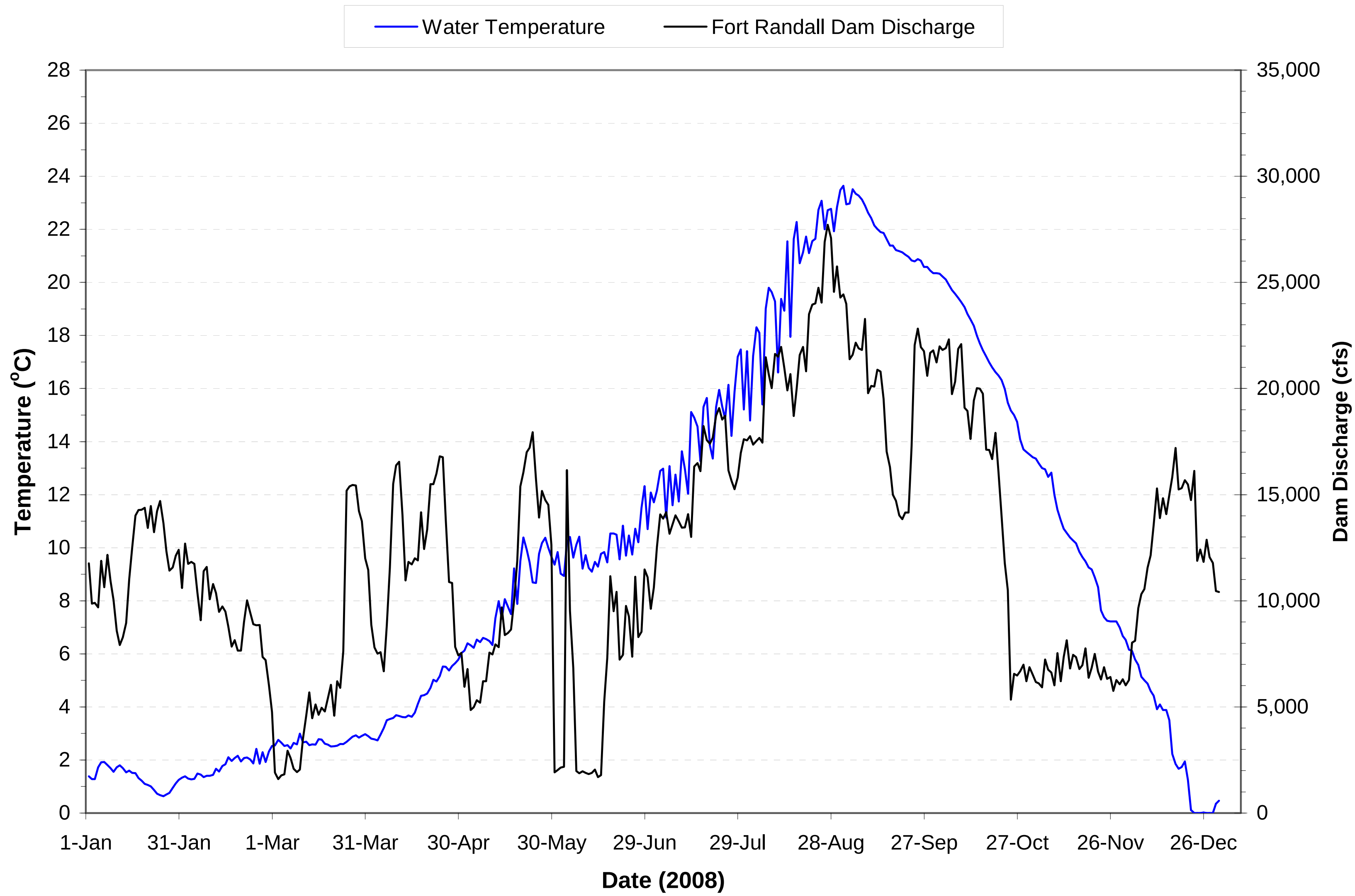


Plate 336. Mean daily water temperature and discharge of the Missouri River at Fort Randall Dam (i.e., site FTRPP1) for 2008. Mean daily temperatures and discharges based on hourly measurements recorded on discharge through Fort Randall Dam.

Plate 337. Summary of water quality conditions monitored in the Niobrara River near Verdel, Nebraska (i.e., site GPTNFNIOBR1) during 2008.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit(A)	No. of Obs.	Mean(B)	Median	Min.	Max.	State WQS Criteria(C)	No. of WQS Exceedences	Percent WQS Exceedence
Streamflow (cfs)	1	5	1,414	1,439	753	2,450	-----	-----	-----
Water Temperature (C)	0.1	5	22.4	22.6	17.1	27.2	29(1,4)	0	0%
Dissolved Oxygen (mg/l)	0.1	4	8.5	8.4	7.5	9.6	5(1,5)	0	0%
Dissolved Oxygen (% Sat.)	0.1	4	105.2	102.0	91.2	125.4	-----	-----	-----
Specific Conductance (umho/cm)	1	5	304	309	255	364	2,000(3)	0	0%
pH (S.U.)	0.1	4	8.5	8.5	8.0	8.8	6.5(1,5), 9.0(1,4)	0	0%
Oxidation-Reduction Potential	1	5	377	326	322	491	-----	-----	-----
Alkalinity, Total (mg/l)	7	5	133	128	121	161	-----	0	0%
Ammonia, Total (mg/l)	0.02	5	-----	n.d.	n.d.	0.26	4.7 (1,4,7), 1.4 (1,6,7)	0	0%
Carbon, Total Organic (mg/l)	0.05	5	6.0	6.0	2.5	11.6	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	5	24	24	6	38	-----	-----	-----
Chloride (mg/l)	1	5	3	3	2	6	250(2,4,9)	0	0%
Dissolved Solids, Total (mg/l)	5	5	212	224	168	262	500(2,4,9)	0	0%
Iron, Dissolved (ug/l)	7	4	-----	10	n.d.	120	1,000(11)	0	0%
Iron, Total (ug/l)	7	5	4,726	3,690	1,760	12,000	300(2,4,9)	5	100%
Kjeldahl N, Total (mg/l)	0.1	5	1.1	1.2	0.7	1.5	-----	-----	-----
Manganese, Total (ug/l)	2	5	265	240	240	340	50(2,4,9)	5	100%
Nitrate-Nitrite N, Total (mg/l)	0.02	5	0.46	0.36	0.04	0.90	10(2,4,9), 100(3,4)	0	0%
Phosphorus, Total (mg/l)	0.02	5	0 22	0.20	0 14	0.28	-----	-----	-----
Sulfate (mg/l)	1	5	24	26	15	30	250(2,4,9)	0	0%
Suspended Solids, Total (mg/l)	4	5	177	150	66	342	-----	-----	-----
Turbidity (NTU)	1	4	189	130	42	453	-----	-----	-----

n.d. = Not detected.

(A) Detection limits given for the parameters Stream Flow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

(1) Criteria for the protection of Class I Warmwater Aquatic Life.
(2) Criteria for the protection of domestic water supply waters.
(3) Criteria for the protection of agricultural water supply waters.
(4) Daily maximum criterion (monitoring results directly comparable to criterion).
(5) Daily minimum criterion (monitoring results directly comparable to criterion).
(6) 30-day average criterion (monitoring results not directly comparable to criterion).
(7) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
(8) Chronic criterion for the protection of freshwater aquatic life.
(9) The criteria for chloride, total dissolved solids, total iron, total manganese, and sulfate are defined by the State of Nebraska to protect the beneficial use of public drinking water. Where the natural background level is greater than these criteria, the State of Nebraska states that the background level is to be used in place of the criteria. The elevated total iron and manganese levels are believed indicative of natural background conditions and are not considered a water quality standards "violation"

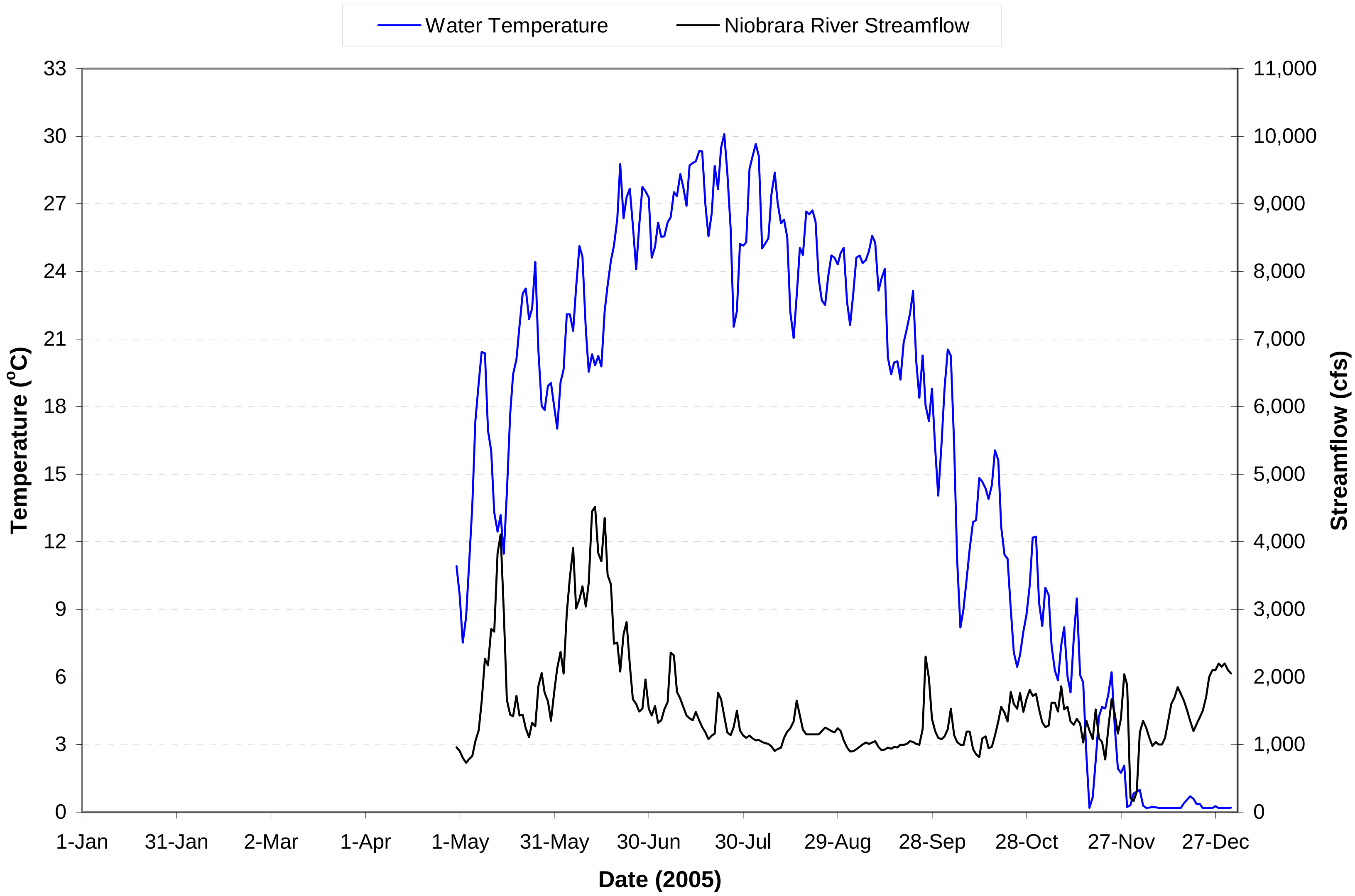


Plate 338. Mean daily water temperature and streamflow of the Niobrara River near Verdel, Nebraska (i.e., site USGS 06465500) for 2005. Mean daily temperatures and streamflows based on hourly measurements recorded at the USGS gaging station.

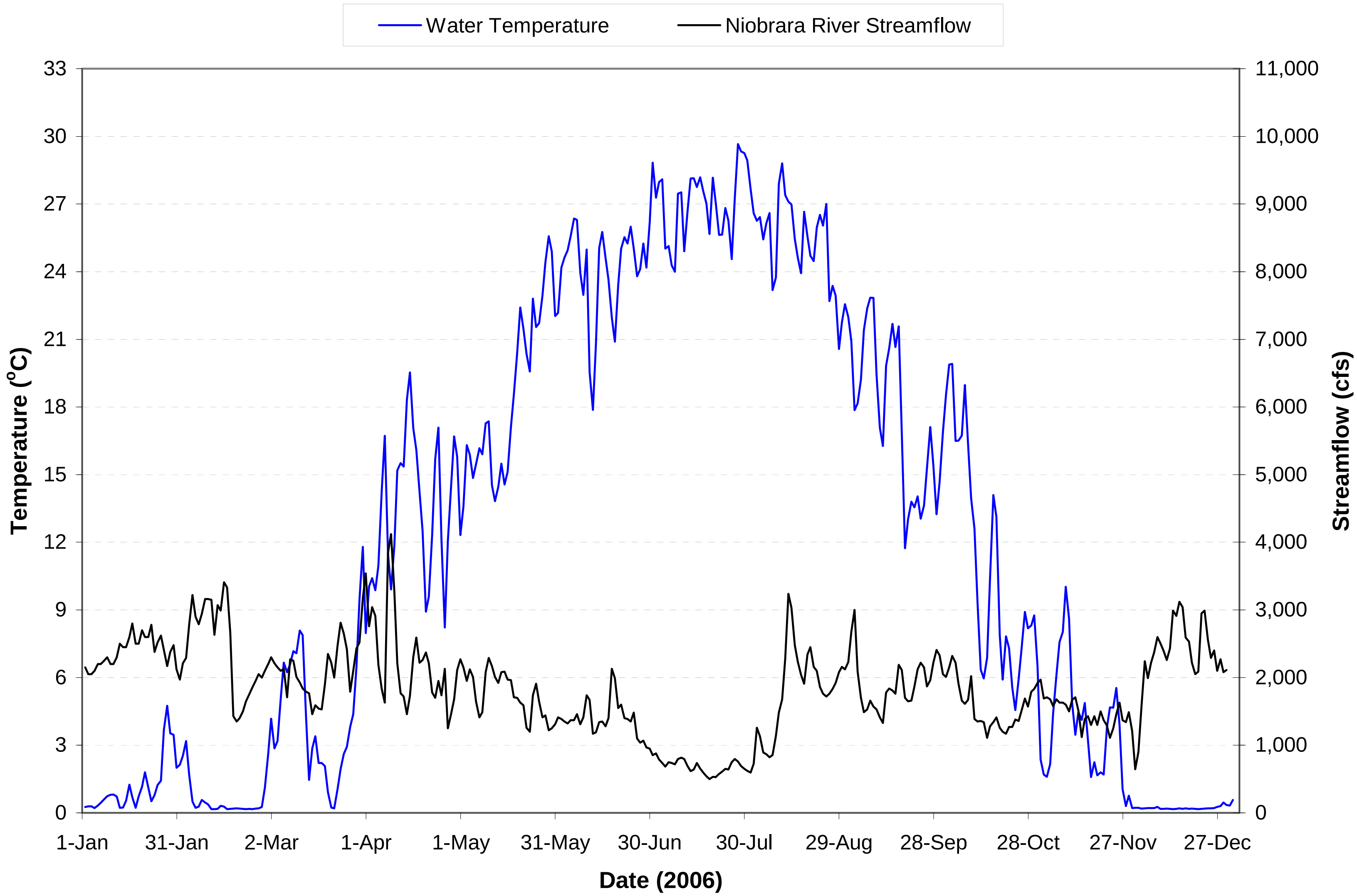


Plate 339. Mean daily water temperature and streamflow of the Niobrara River near Verdel, Nebraska (i.e., site USGS 06465500) for 2006. Mean daily temperatures and streamflows based on hourly measurements recorded at the USGS gaging station.

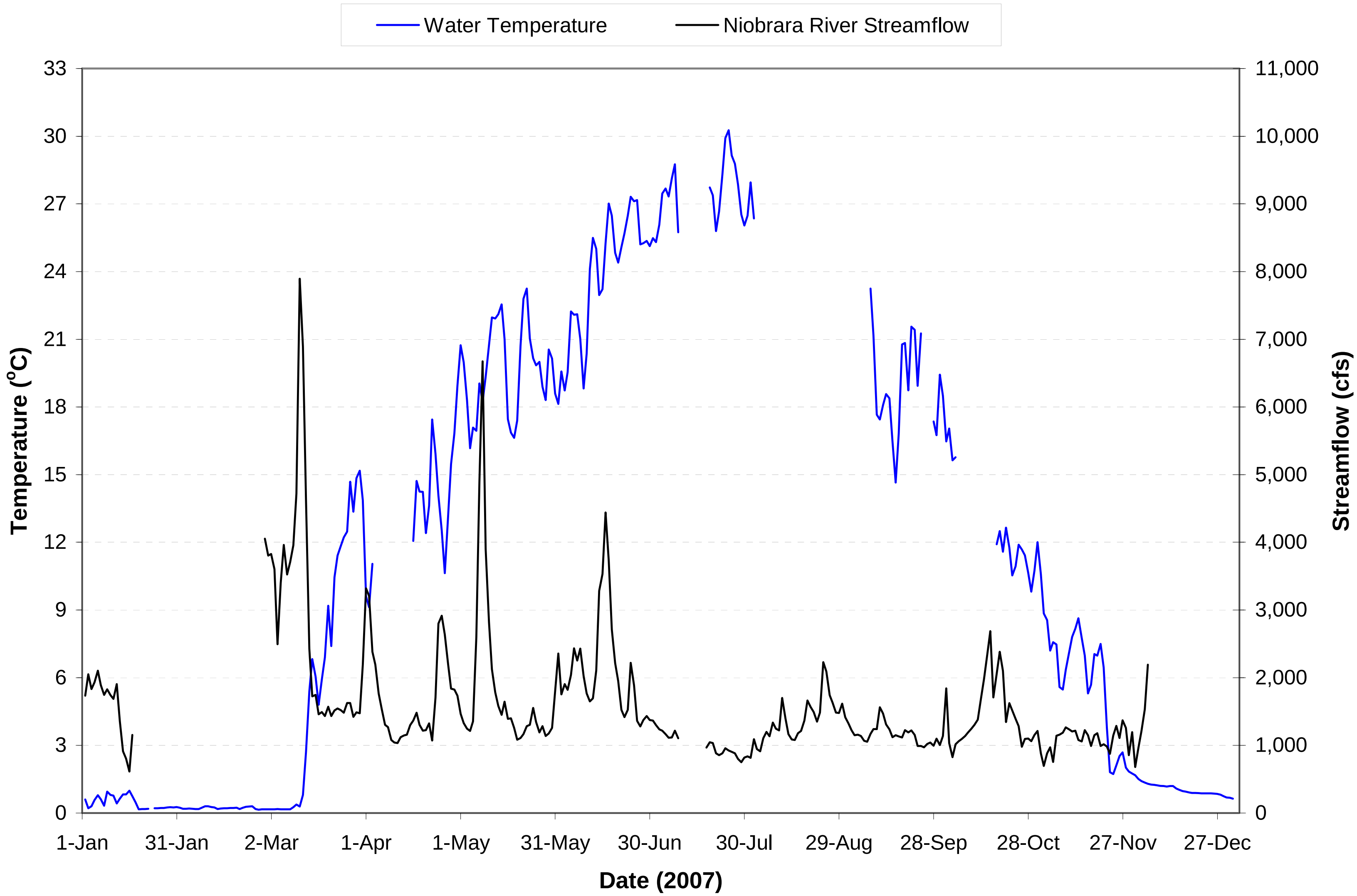


Plate 340. Mean daily water temperature and streamflow of the Niobrara River near Verdel, Nebraska (i.e., site USGS 06465500) for 2007. Mean daily temperatures and streamflows based on hourly measurements recorded at the USGS gaging station.

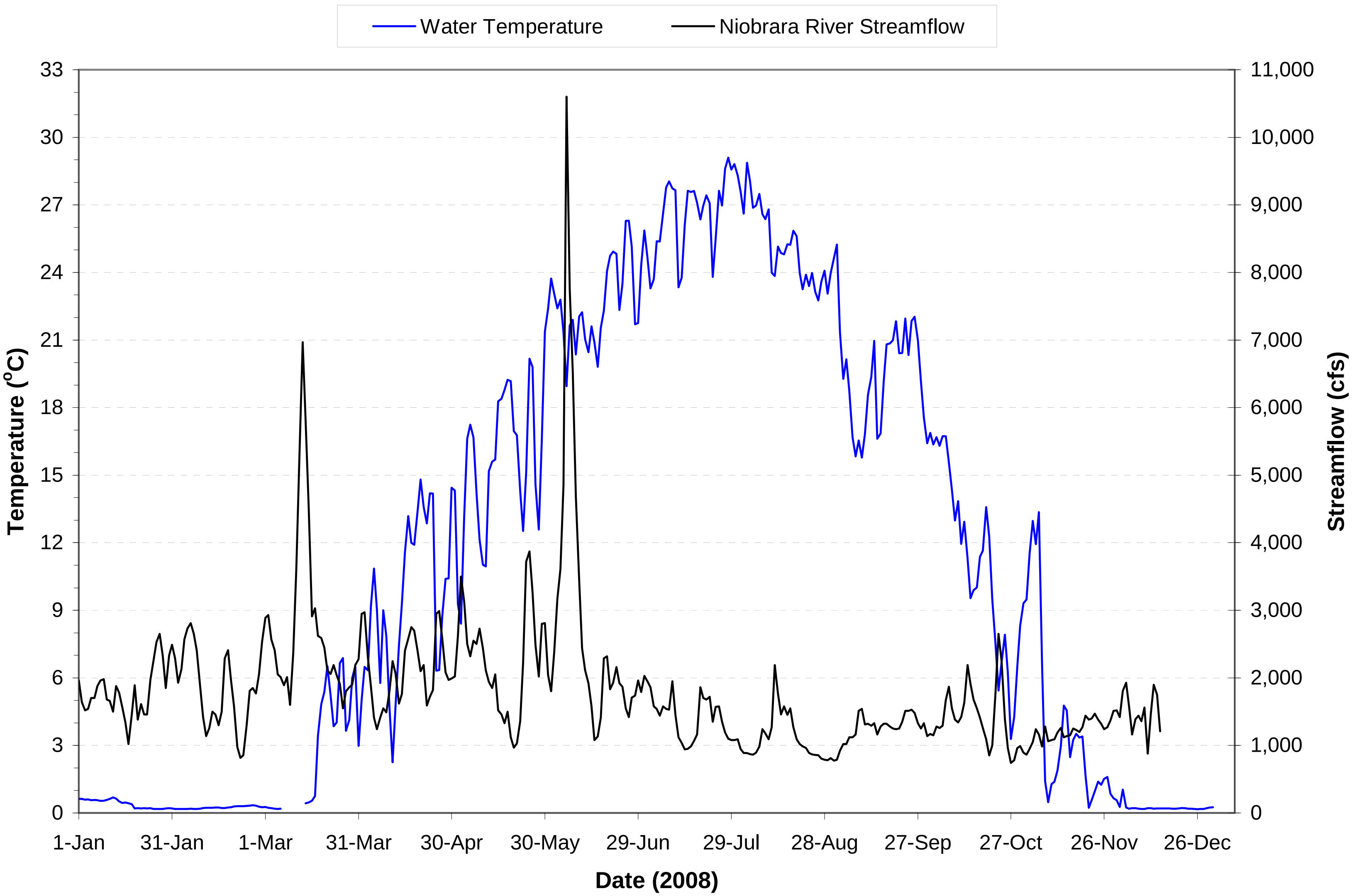


Plate 341. Mean daily water temperature and streamflow of the Niobrara River near Verdel, Nebraska (i.e., site USGS 06465500) for 2008. Mean daily temperatures and streamflows based on hourly measurements recorded at the USGS gaging station.

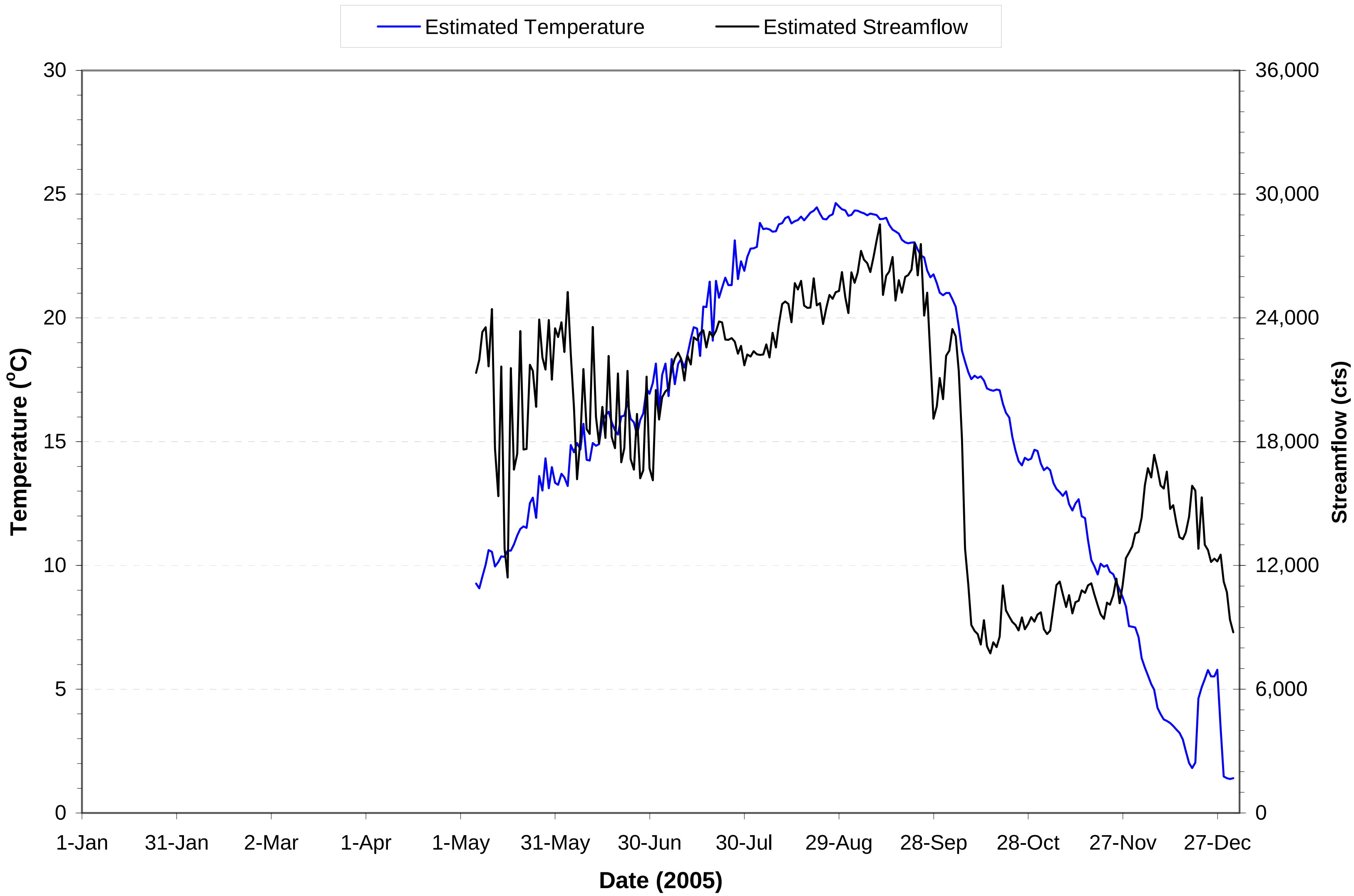


Plate 342. Mean daily water temperature and streamflow estimated for the Missouri River inflow to Gavins Point Reservoir for 2005. The mean daily discharge was estimated by adding the mean daily discharges determined for the Fort Randall Dam outflow and Niobrara River near Verdel, Nebraska at USGS gaging station 06465500. The mean daily temperature was estimated by flow weighting the mean daily water temperatures determined at the two sites.

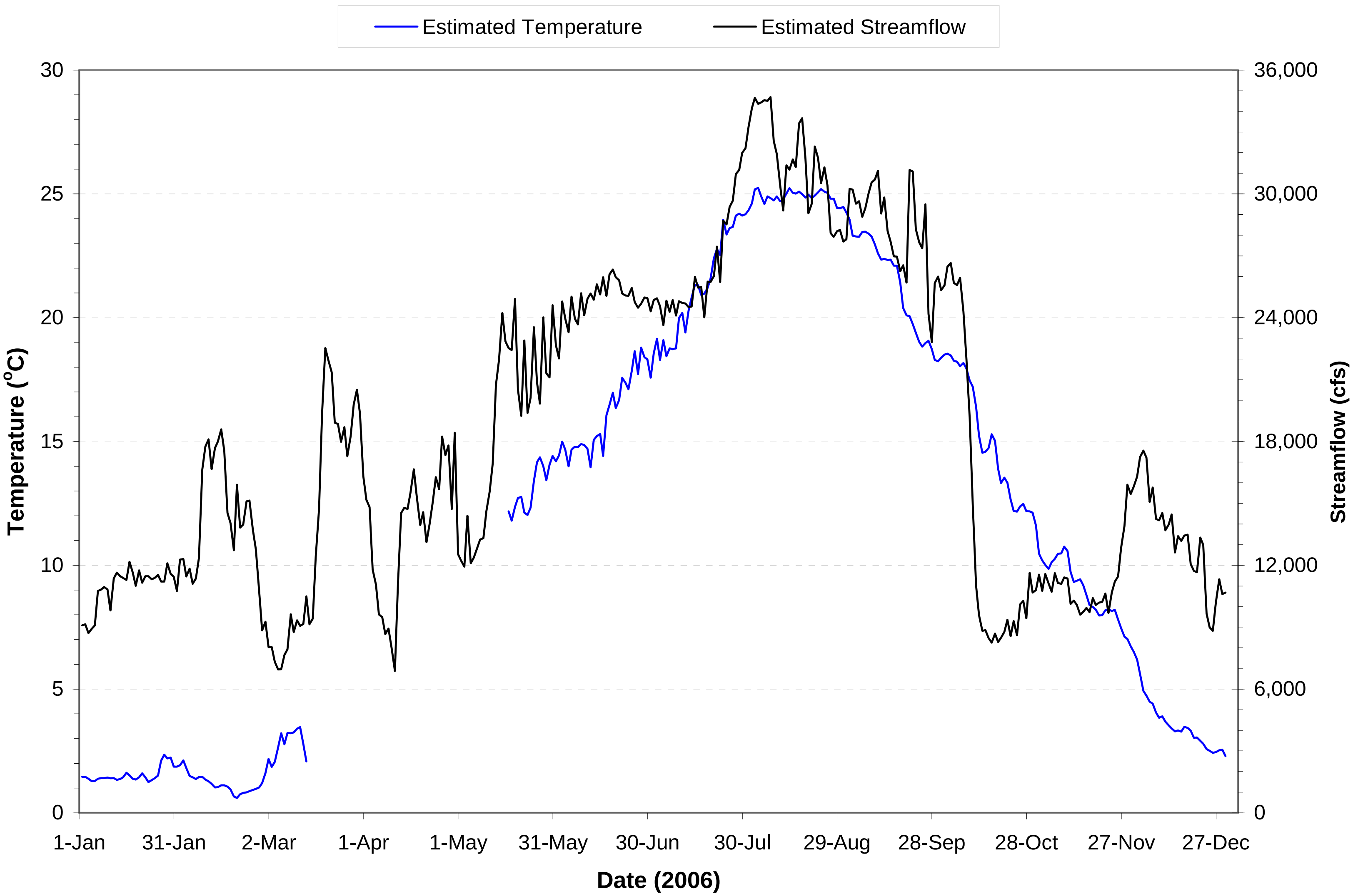


Plate 343. Mean daily water temperature and streamflow estimated for the Missouri River inflow to Gavins Point Reservoir for 2006. The mean daily discharge was estimated by adding the mean daily discharges determined for the Fort Randall Dam outflow and Niobrara River near Verdel, Nebraska at USGS gaging station 06465500. The mean daily temperature was estimated by flow weighting the mean daily water temperatures determined at the two sites. (Note: Gaps in temperature plots are periods when monitoring equipment was not operational.)

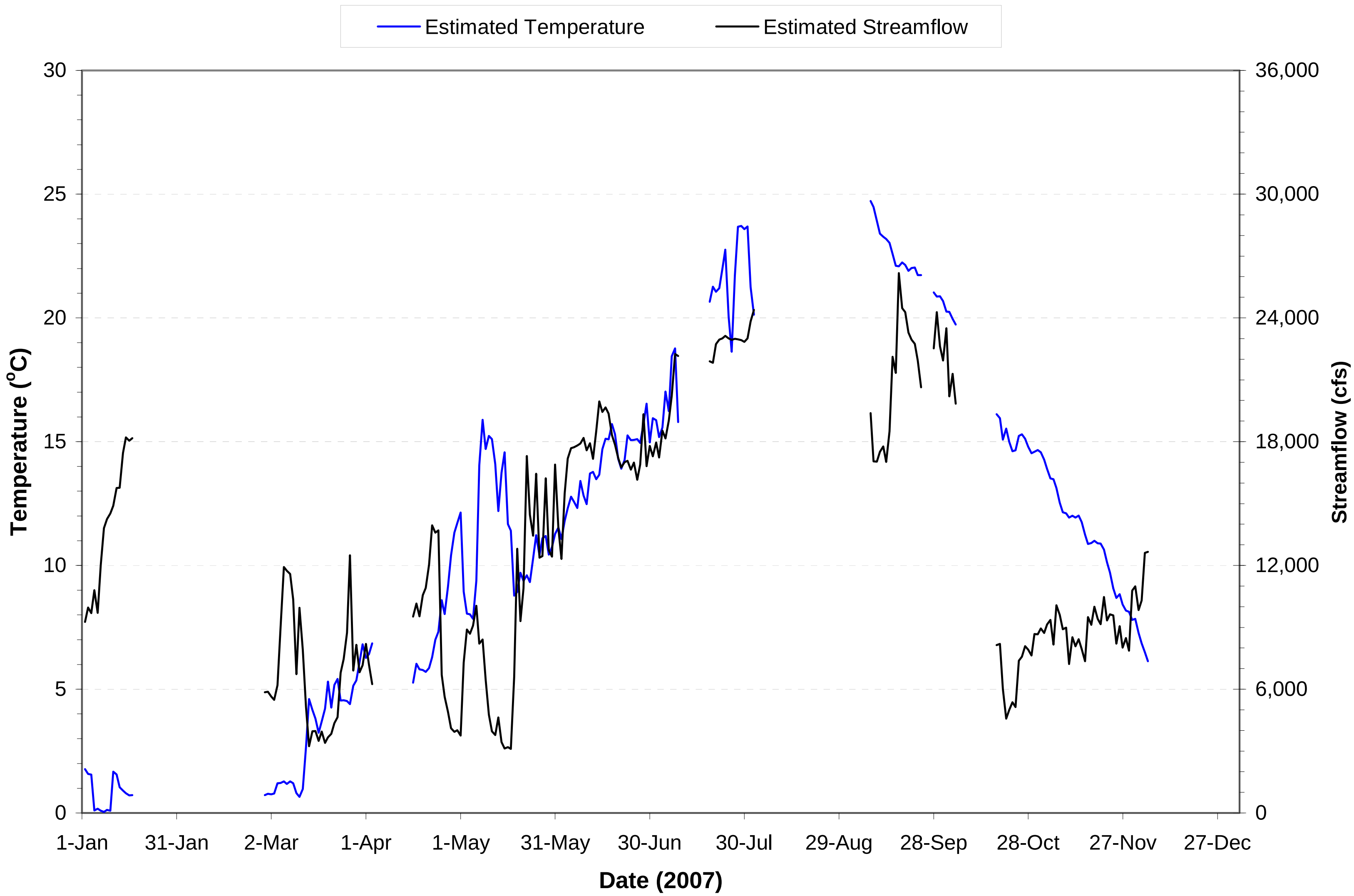


Plate 344. Mean daily water temperature and streamflow estimated for the Missouri River inflow to Gavins Point Reservoir for 2007. The mean daily discharge was estimated by adding the mean daily discharges determined for the Fort Randall Dam outflow and Niobrara River near Verdel, Nebraska at USGS gaging station 06465500. The mean daily temperature was estimated by flow weighting the mean daily water temperatures determined at the two sites. (Note: Gaps in temperature plots are periods when monitoring equipment was not operational.)

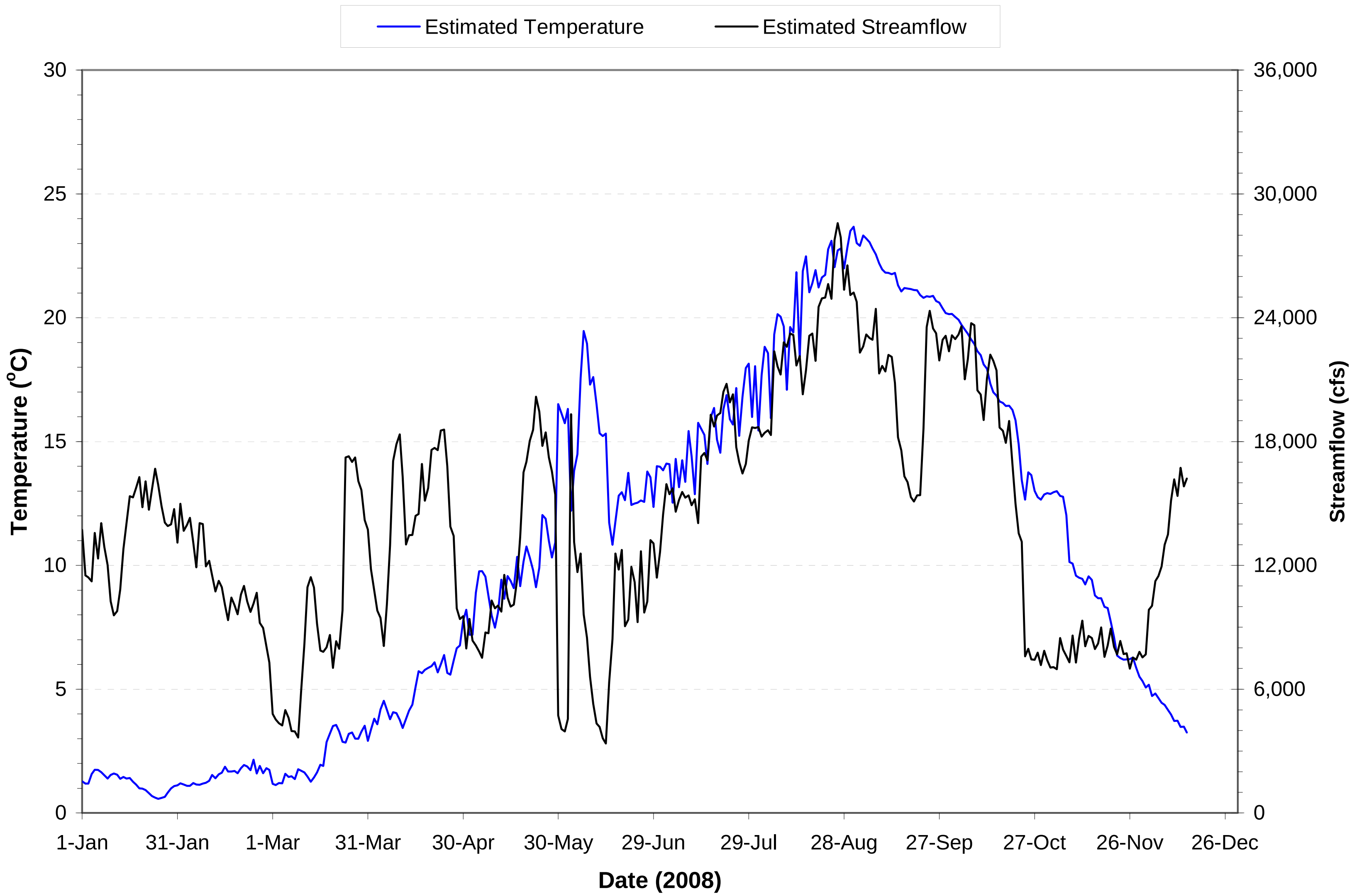


Plate 345. Mean daily water temperature and streamflow estimated for the Missouri River inflow to Gavins Point Reservoir for 2008. The mean daily discharge was estimated by adding the mean daily discharges determined for the Fort Randall Dam outflow and Niobrara River near Verdel, Nebraska at USGS gaging station 06465500. The mean daily temperature was estimated by flow weighting the mean daily water temperatures determined at the two sites.

Plate 346. Summary of water quality conditions monitored on water discharged through Gavins Point Dam (i.e., site GTPPP1) during the 5-year period of 2004 through 2008.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit[A]	No. of Obs.	Mean[B]	Median	Min.	Max.	State WQS Criteria[C]	No. of WQS Exceedences	Percent WQS Exceedence
Dam Discharge (cfs)	1	48	17,093	16,000	8,000	30,000	-----	-----	-----
Water Temperature (C)	0.1	45	14.0	14.3	0.8	26.3	27[1,2,6], 29[1,2,6]	0	0%
Dissolved Oxygen (mg/l)	0.1	44	9.5	9.4	2.6	13.5	5[1,7]	1	2%
Dissolved Oxygen (% Sat.)	0.1	44	93.2	95.4	20.1	115.1	-----	-----	-----
Specific Conductance (umho/cm)	1	44	649	671	463	744	2,000[4]	0	0%
pH (S.U.)	0.1	43	8.3	8.3	7.1	8.9	6 5[1,3,7], 9.0[1,3,6], 9.5[5,6]	0	0%
Oxidation-Reduction Potential	1	27	368	370	252	503	-----	-----	-----
Alkalinity, Total (mg/l)	7	48	161	160	129	197	-----	0	0%
Ammonia, Total (mg/l)	0.02	48	-----	0.04	n.d.	0.44	4.7 [1,6,9], 1.4 [1,8,9]	0	0%
Carbon, Total Organic (mg/l)	0.05	47	3.5	3.0	1.2	13.8	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	31	11	10	n.d.	35	-----	-----	-----
Chloride (mg/l)	1	29	11	11	8	19	175[1,6], 100[1,8], 438[3,6], 250[3,8,13]	0	0%
Dissolved Solids, Total (mg/l)	5	48	440	450	310	542	1750[3,6], 1000[3,8], 3500[5,6], 2000[5,8], 500[3,13]	0, 0, 0, 0, 1	0%, 0%, 0%, 0%, 2%
Hardness, Total (mg/l)	0.4	7	214	211	208	229	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	48	0.6	0.5	n.d.	1.8	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	48	-----	n.d.	n.d.	0.60	10[3,6,, 100[4,6]	0	0%
Phosphorus, Total (mg/l)	0.02	48	0.07	0.05	n.d.	0.38	-----	-----	-----
Sulfate (mg/l)	1	48	187	190	95	230	875[3,6], 500[3,8], 250[3,13]	0	0%
Suspended Solids, Total (mg/l)	4	48	13	10	n.d.	45	158[1,6], 90[1,8]	0	0%
Turbidity (NTU)	1	22	51	11	1	824	-----	-----	-----
Aluminum, Dissolved (mg/l)	25	4	-----	n.d.	n.d.	26	750[10], 87[11], 200[12]	0	0%
Antimony, Dissolved (ug/l)	6	4	-----	n.d.	n.d.	n.d.	88[10], 30[11], 6[12]	0	0%
Arsenic, Dissolved (ug/l)	3	7	-----	n.d.	n.d.	3	340[10], 16.7[11], 10[12]	0	0%
Barium, Dissolved (ug/l)	5	2	47	47	44	49	2,000[11]	0	0%
Beryllium, Dissolved (ug/l)	2	4	-----	n.d.	n.d.	n.d.	130[10], 5.3[11], 4[12]	0	0%
Cadmium, Dissolved (ug/l)	0.2	7	-----	n.d.	n.d.	n.d.	12[10], 0.41[11], 5[12]	0	0%
Chromium, Dissolved (ug/l)	10	7	-----	n.d.	n.d.	n.d.	1,092[10], 142[11], 100[12]	0	0%
Copper, Dissolved (ug/l)	2	7	-----	8	n.d.	15	27[10], 17[11], 1,000[12]	0	0%
Iron, Dissolved (ug/l)	40	30	-----	n.d.	n.d.	246	1,000[11]	0	0%
Iron, Total (ug/l)	40	31	392	356	70	1,620	300[3,13]	18	58%
Lead, Dissolved (ug/l)	0.5	7	-----	n.d.	n.d.	n.d.	144[10], 5.6[11], 15[12]	0	0%
Manganese, Total (ug/l)	2	31	69	51	6	290	50[3,13]	16	52%
Mercury, Dissolved (ug/l)	0.02	8	-----	n.d.	n.d.	n.d.	1.4[10]	0	0%
Mercury, Total (ug/l)	0.02	8	-----	n.d.	n.d.	n.d.	0.77[11], 2[12]	0	0%
Nickel, Dissolved (ug/l)	10	7	-----	n.d.	n.d.	n.d.	880[10], 98[11], 100[12]	0	0%
Selenium, Total (ug/l)	1	6	-----	n.d.	n.d.	n.d.	20[4,10], 5[11], 50[12]	0	0%
Silver, Dissolved (ug/l)	1	7	-----	n.d.	n.d.	n.d.	12[10], 100[12]	0	0%
Thallium, Dissolved (ug/l)	0.5	4	-----	n.d.	n.d.	n.d.	1,400[10], 6.3[11], 2[12]	0	0%
Zinc, Dissolved (ug/l)	5	7	-----	n.d.	n.d.	13	221[10,11], 5,000[12]	0	0%
Pesticide Scan (ug/l)[E]	0.05	5	-----	n.d.	n.d.	n.d.	-----	-----	-----

n d = Not detected

[A] Detection limits given for the parameters Dam Discharge, Water Temperature, Dissolved Oxygen (mg/l and % Sat), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters

[B] Nondetect values set to 0 to calculate mean If 20% or more of observations were n d , mean is not reported The mean value reported for pH is an arithmetic mean (i e , log conversion of logarithmic pH values was not done to calculate mean)

[C] Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- [1] Criteria for the protection of Warmwater Permanent Fish Life Propagation Waters (South Dakota) or Class I Warmwater Aquatic Life (Nebraska)
- [2] South Dakota's temperature criterion is 27 C and Nebraska's is 29 C
- [3] Criteria for the protection of domestic water supply waters
- [4] Criteria for the protection of agricultural water supply waters
- [5] Criteria for the protection of commerce and industry waters
- [6] Daily maximum criterion (monitoring results directly comparable to criterion)
- [7] Daily minimum criterion (monitoring results directly comparable to criterion)
- [8] 30-day average criterion (monitoring results not directly comparable to criterion)
- [9] Total ammonia criteria pH and temperature dependent Criteria listed are for the median pH and temperature conditions
- [10] Acute (CMC) criterion for the protection of freshwater aquatic life
- [11] Chronic (CCC) criterion for the protection of freshwater aquatic life
- [12] Criterion for the protection of human health
- [13] The criteria for chloride, total dissolved solids, total iron, total manganese, and sulfate are defined by the State of Nebraska to protect the beneficial use of public drinking water Where the natural background level is greater than these criteria, the State of Nebraska states that the background level is to be used in place of the criteria The elevated total iron and manganese levels are believed indicative of natural background conditions and are not considered a water quality standards "violation"

Note: Some of South Dakota's and Nebraska's criteria for metals (i e , cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness Criteria shown for those metals were calculated using the median hardness value

[E] The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, cycloate, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, isopropalin, metolachlor, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, phorate, profluralin, prometon, propachlor, propazine, simazine, terbufos, triallate, trifluralin, and vernolate Individual pesticides were not detected unless listed under pesticide scan

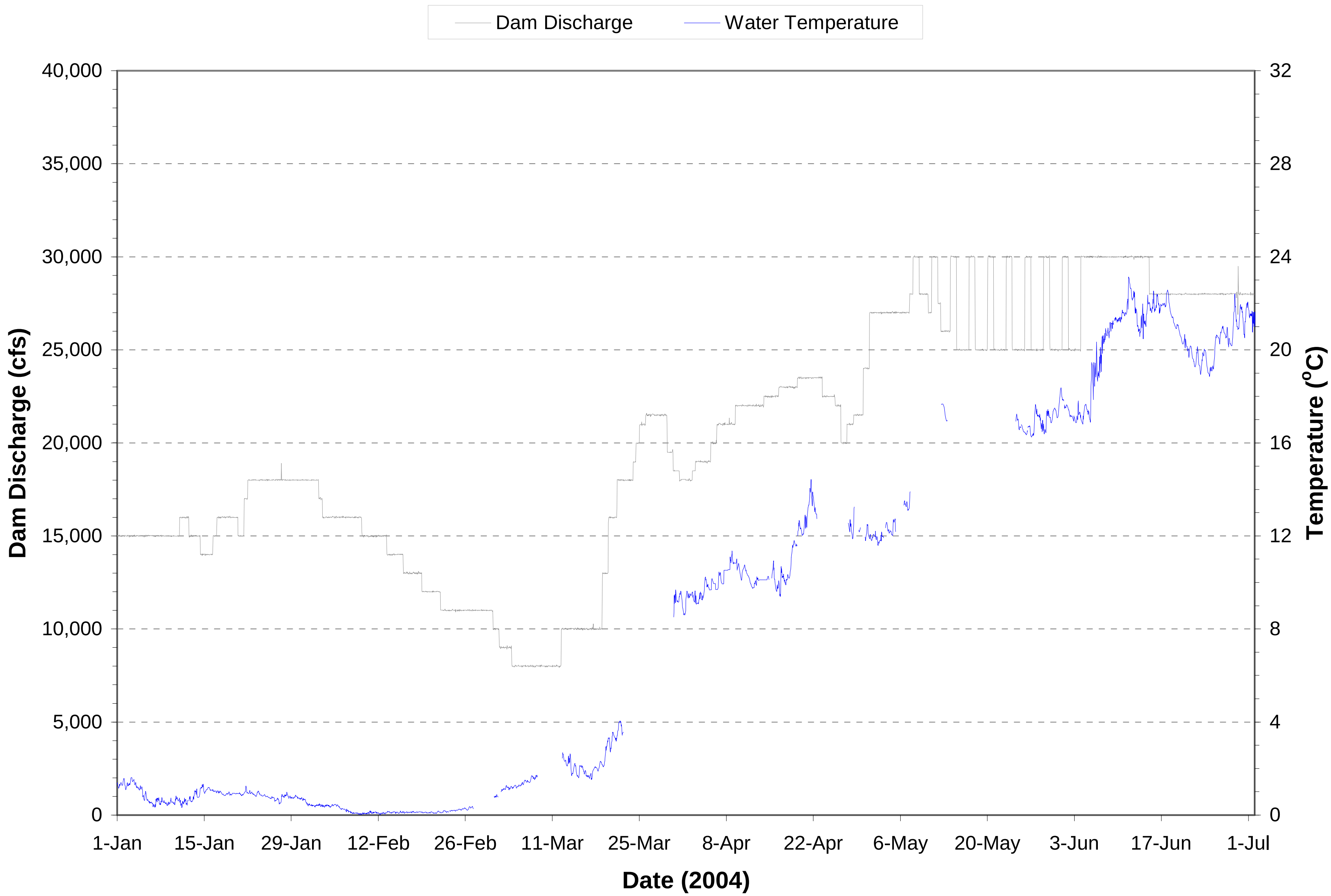


Plate 347. Hourly discharge and water temperature monitored at the Gavins Point powerplant on water discharged through the dam during the period January through June 2004.
Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.

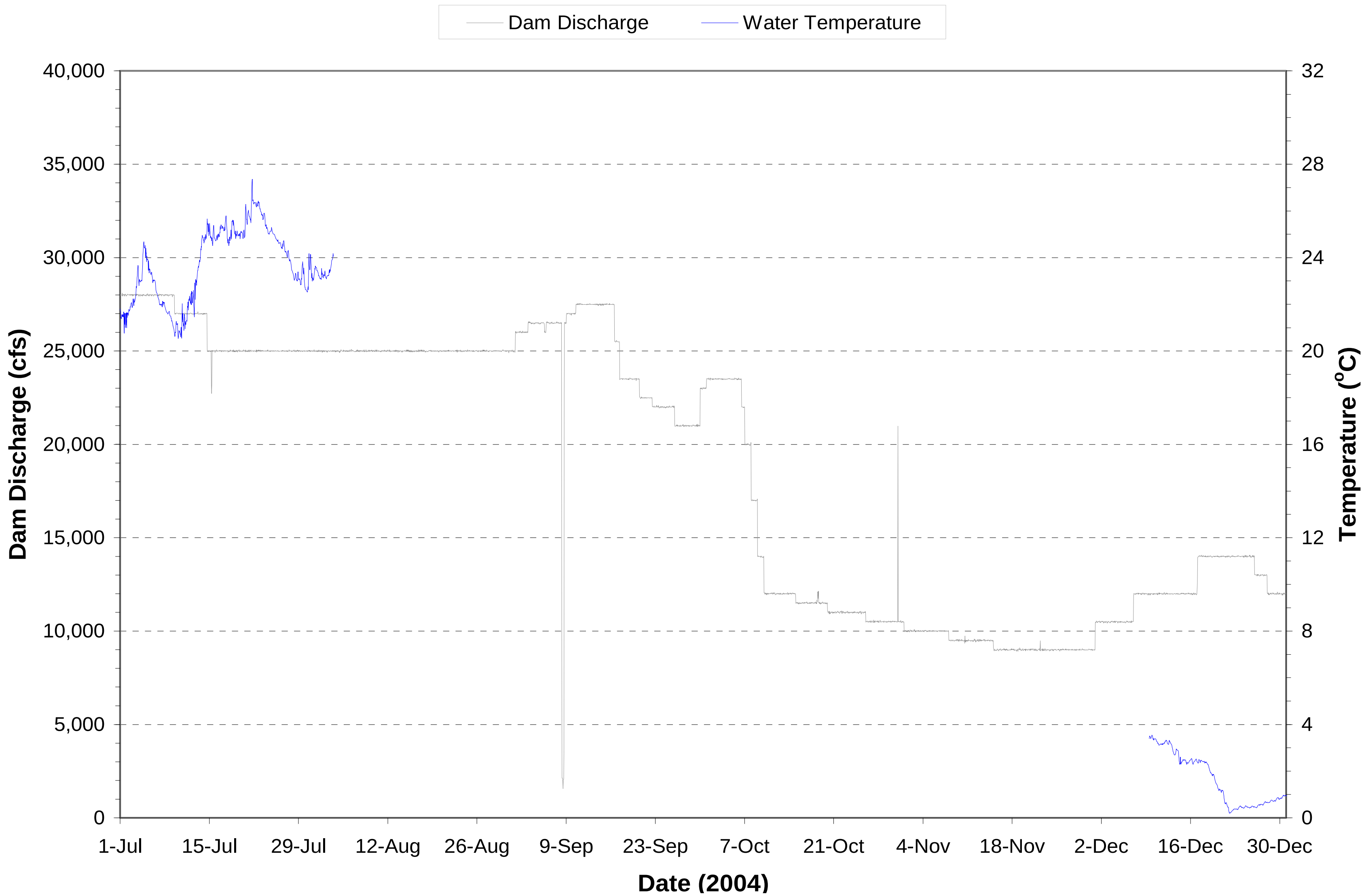


Plate 348. Hourly discharge and water temperature monitored at the Gavins Point powerplant on water discharged through the dam during the period July through December 2004.
Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.

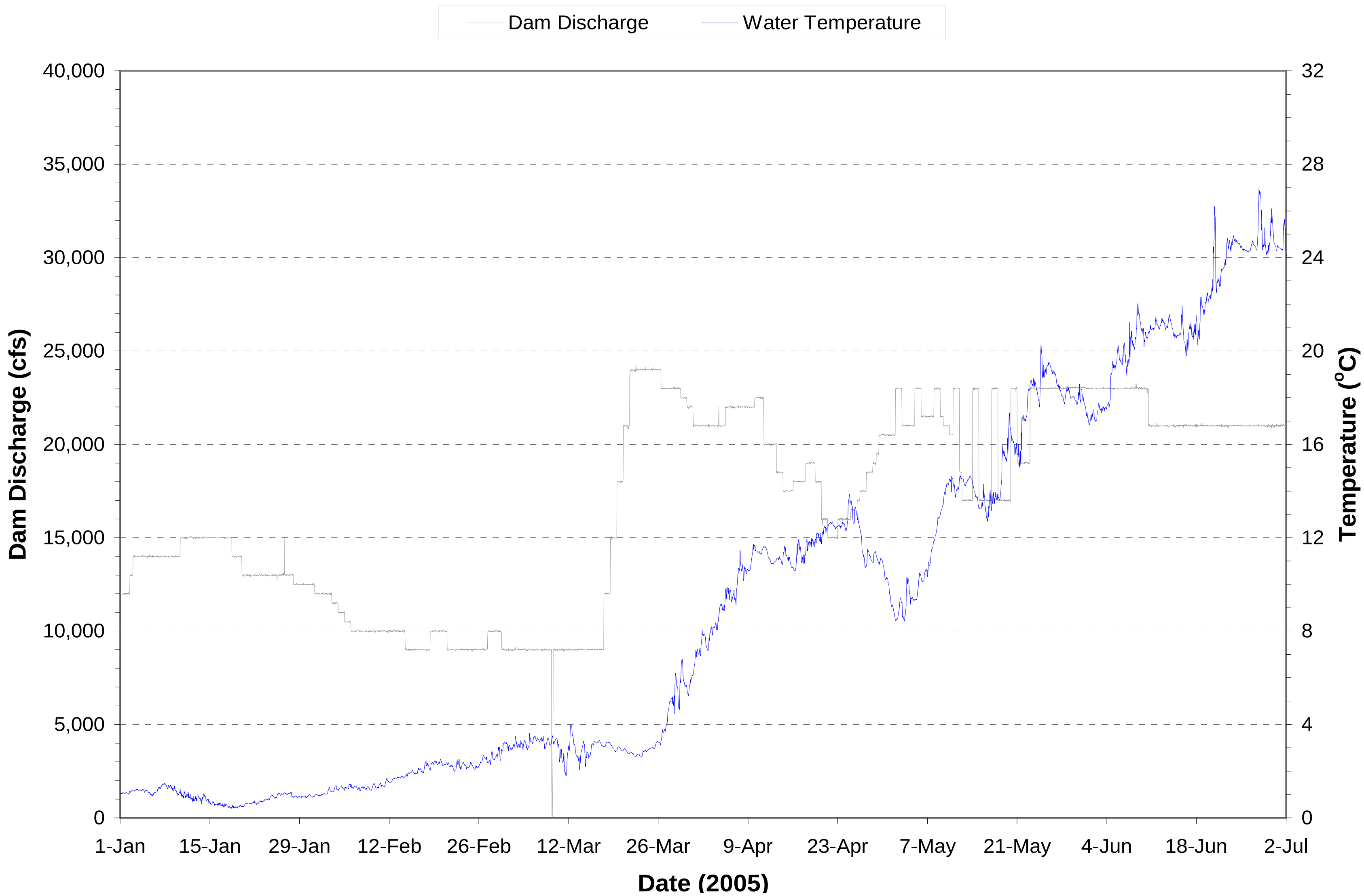


Plate 349. Hourly discharge and water temperature monitored at the Gavins Point powerplant on water discharged through the dam during the period January through June 2005.

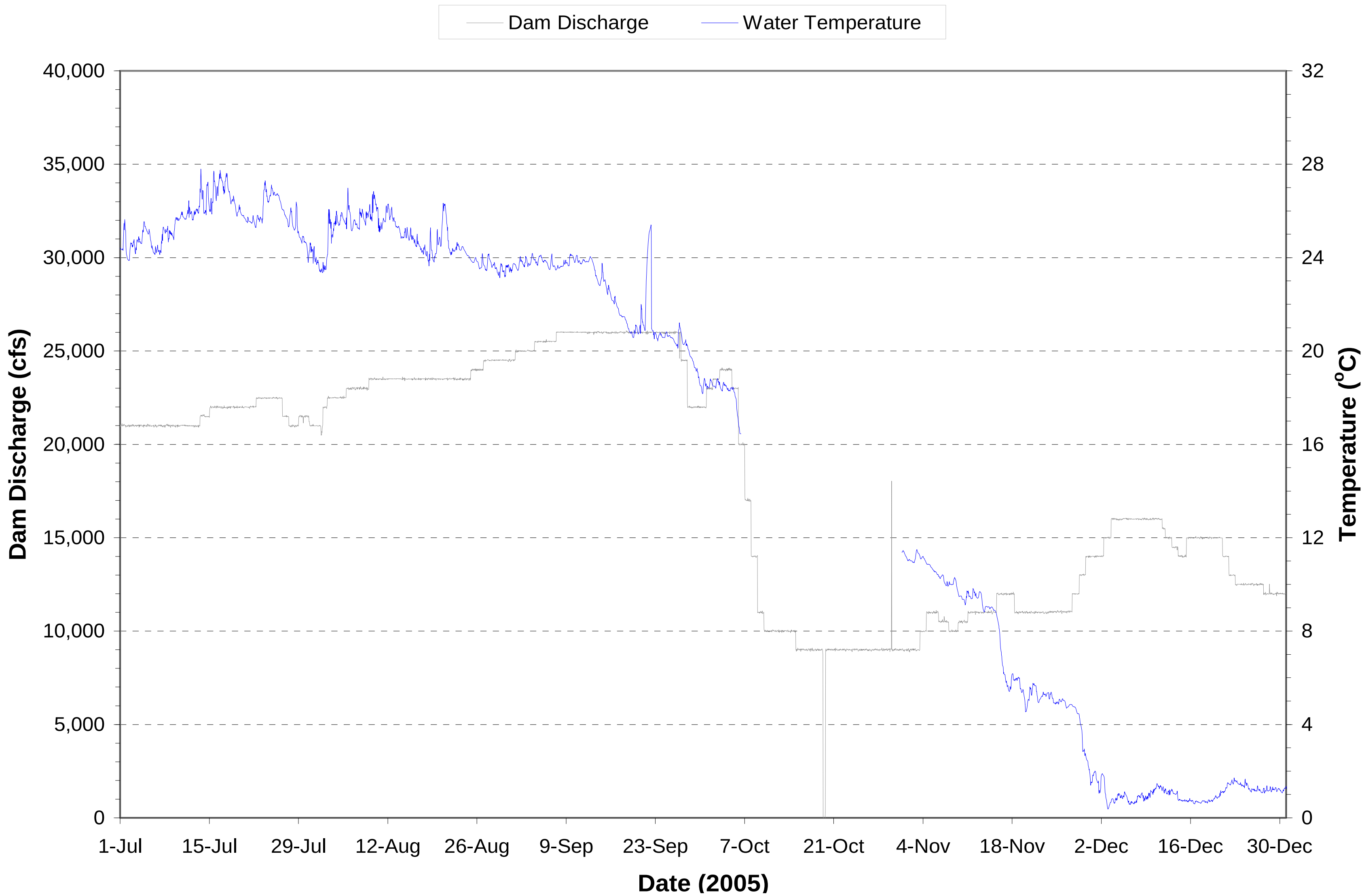


Plate 350. Hourly discharge and water temperature monitored at the Gavins Point powerplant on water discharged through the dam during the period July through December 2005.
Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.

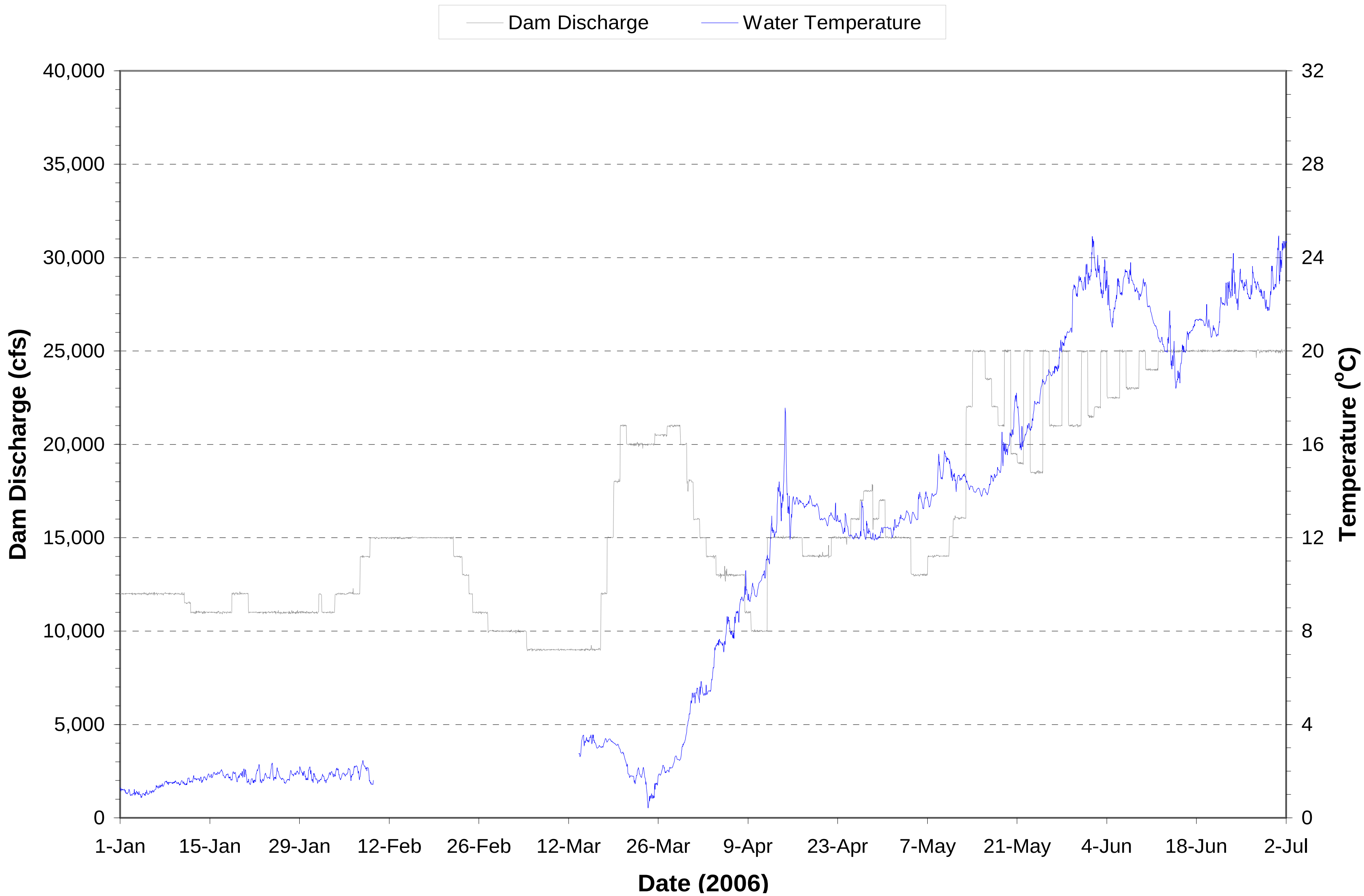


Plate 351. Hourly discharge and water temperature monitored at the Gavins Point powerplant on water discharged through the dam during the period January through June 2006.
Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.

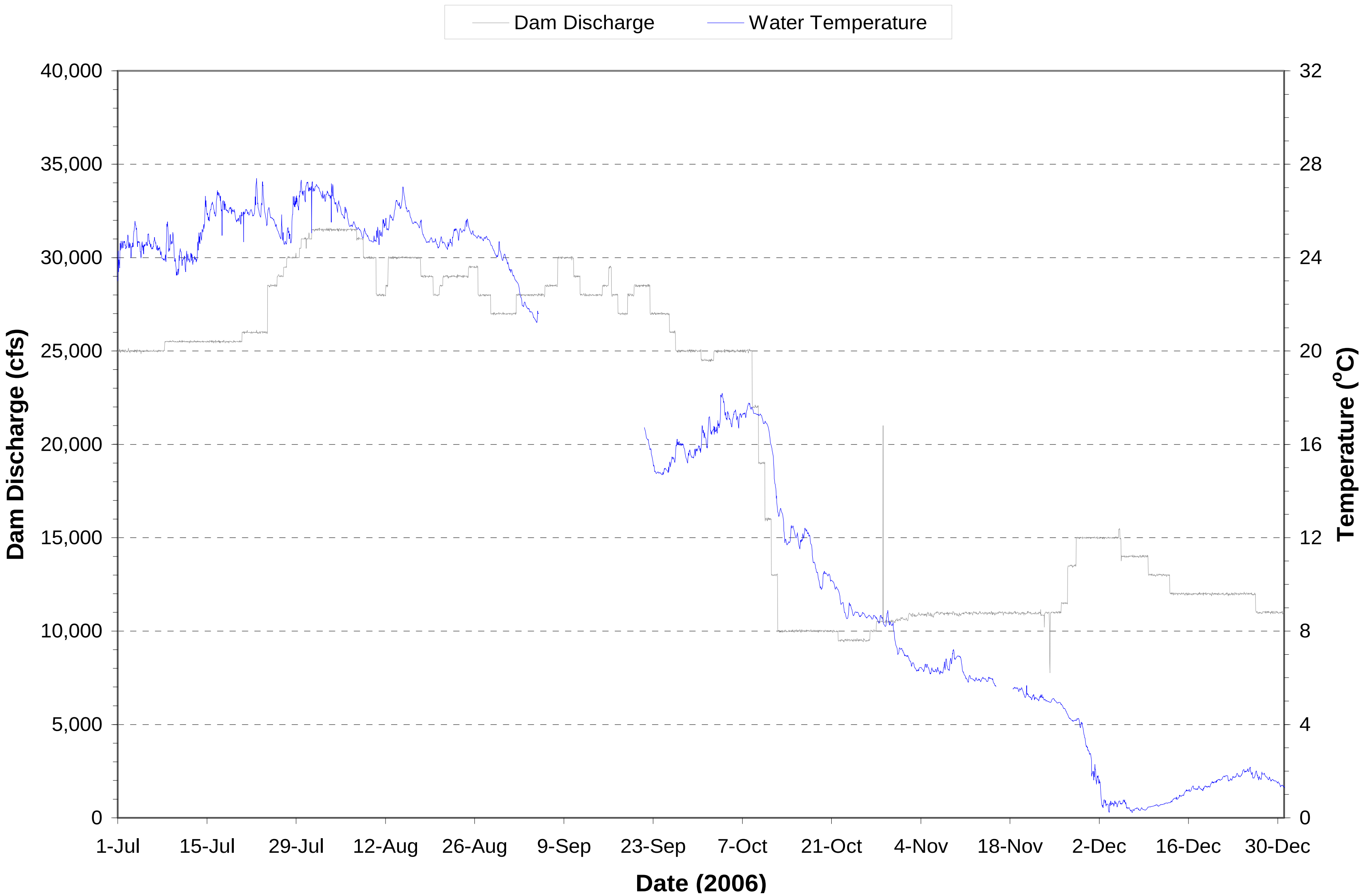


Plate 352. Hourly discharge and water temperature monitored at the Gavins Point powerplant on water discharged through the dam during the period July through December 2006.
Note: Gaps in temperature plot represents periods when monitoring equipment was not operational.

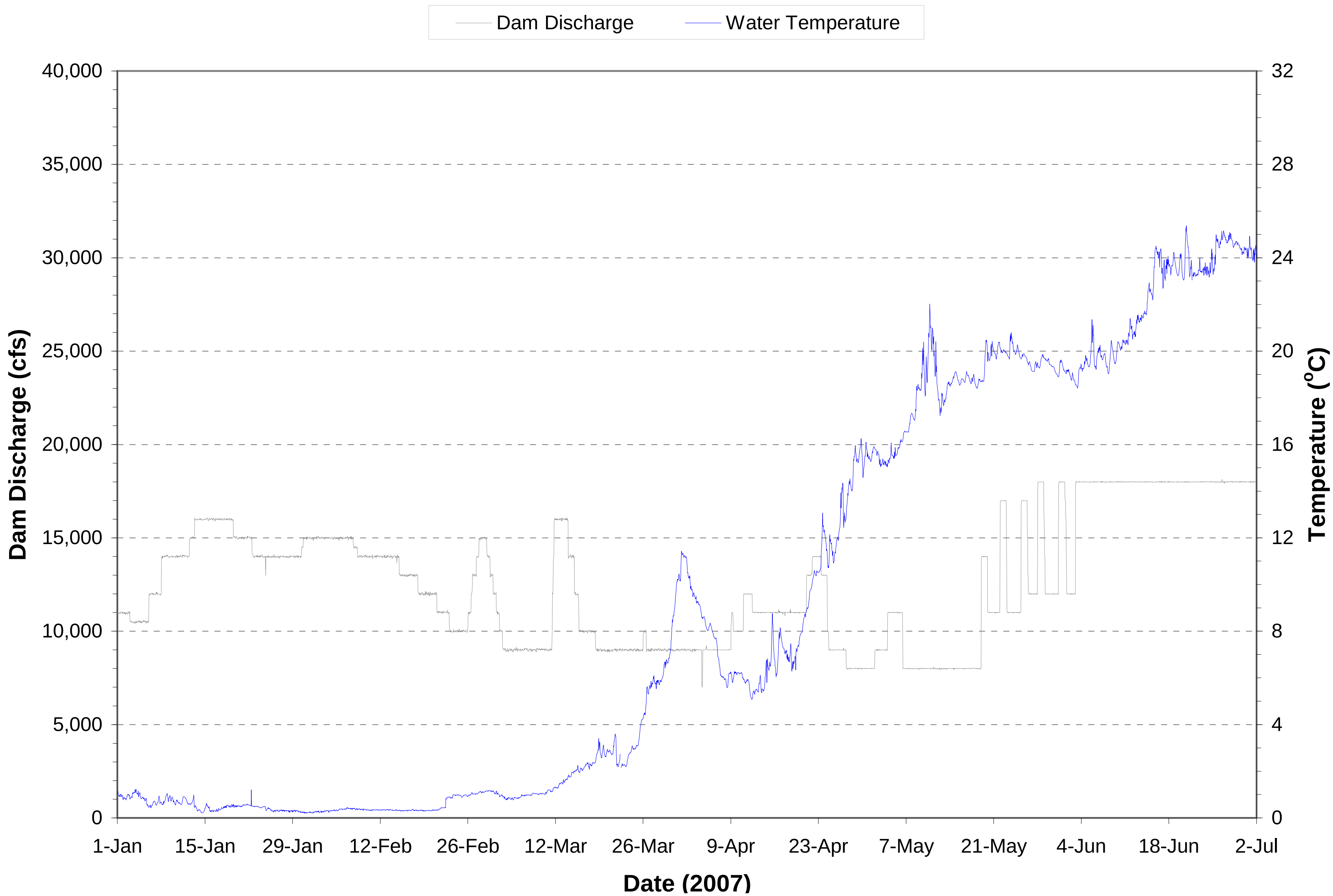


Plate 353. Hourly discharge and water temperature monitored at the Gavins Point powerplant on water discharged through the dam during the period January through June 2007.

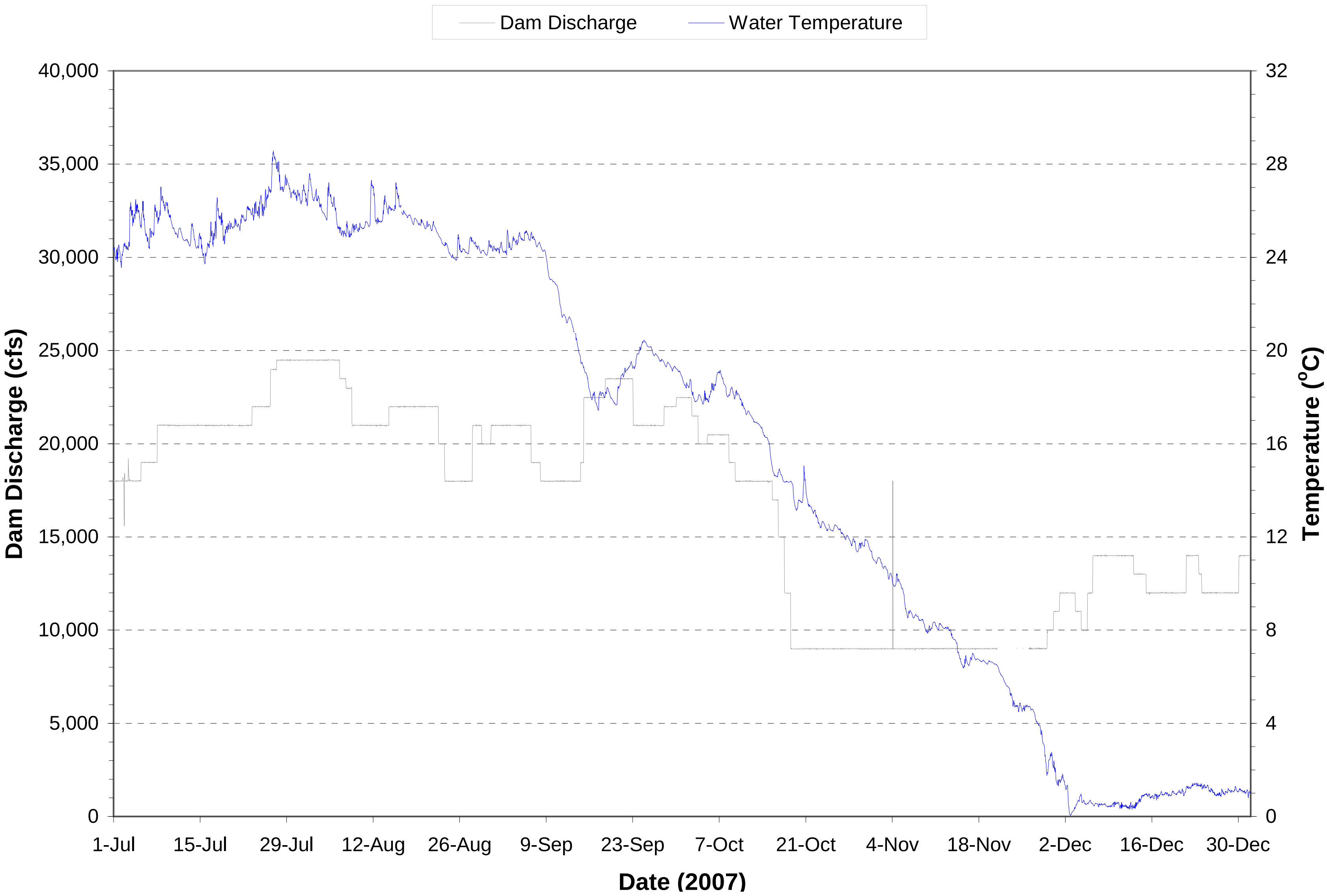


Plate 354. Hourly discharge and water temperature monitored at the Gavins Point powerplant on water discharged through the dam during the period July through December 2007.

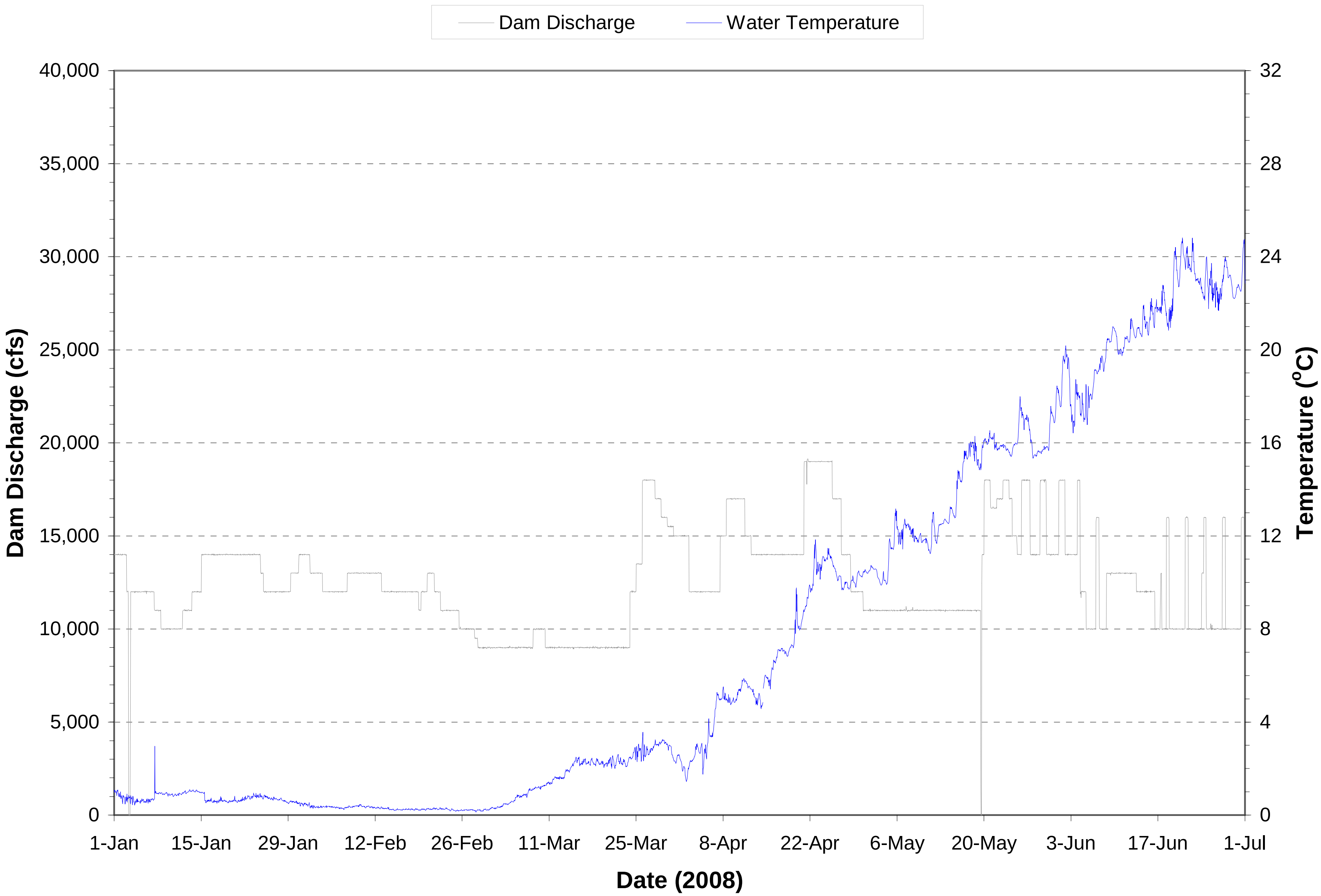


Plate 355. Hourly discharge and water temperature monitored at the Gavins Point powerplant on water discharged through the dam during the period January through June 2008.

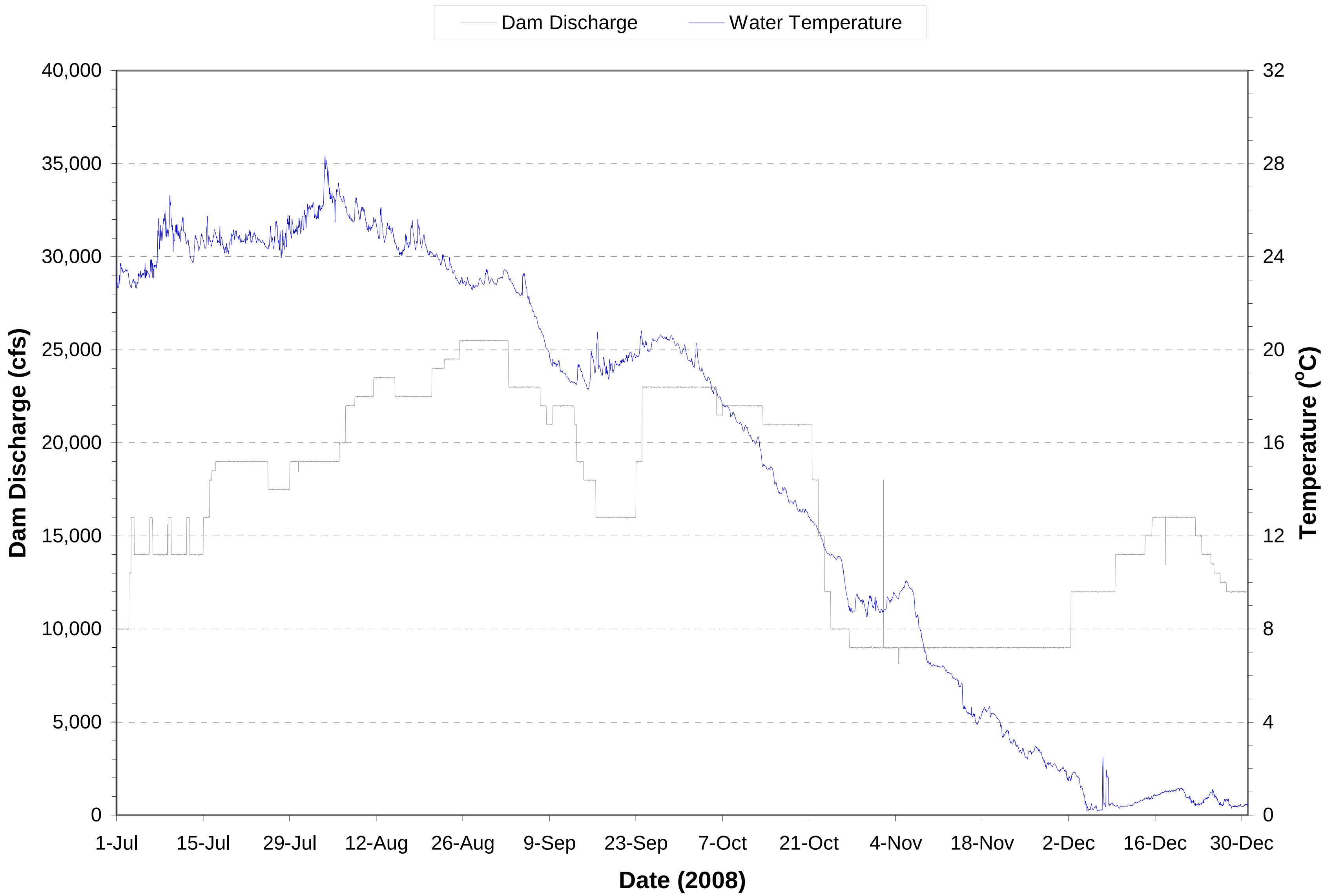


Plate 356. Hourly discharge and water temperature monitored at the Gavins Point powerplant on water discharged through the dam during the period July through December 2008.

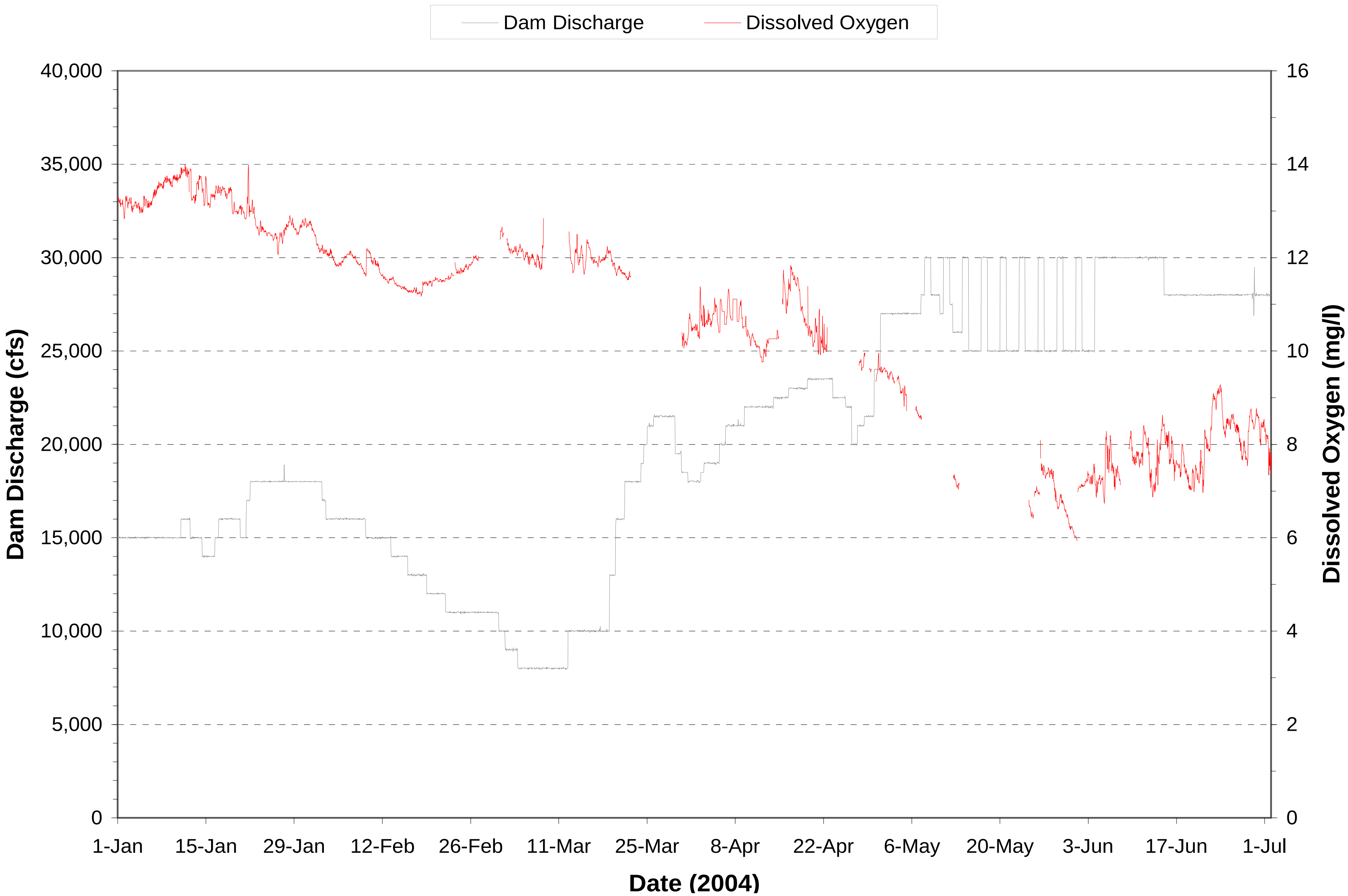


Plate 357. Hourly discharge and dissolved oxygen monitored at the Gavins Point powerplant on water discharged through the dam during the period January through June 2004.
Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.

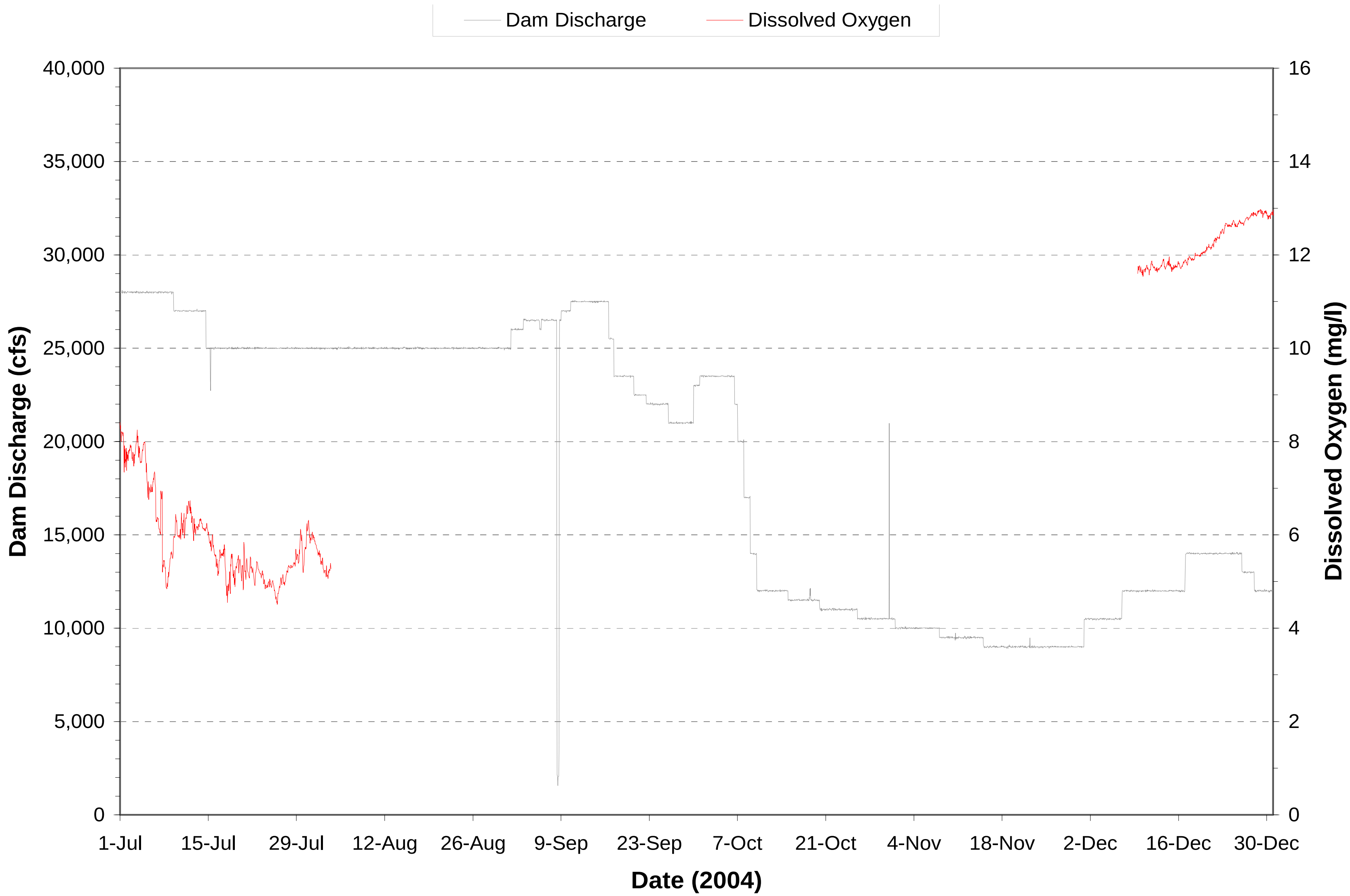


Plate 358. Hourly discharge and dissolved oxygen monitored at the Gavins Point powerplant on water discharged through the dam during the period July through December 2004.
Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.

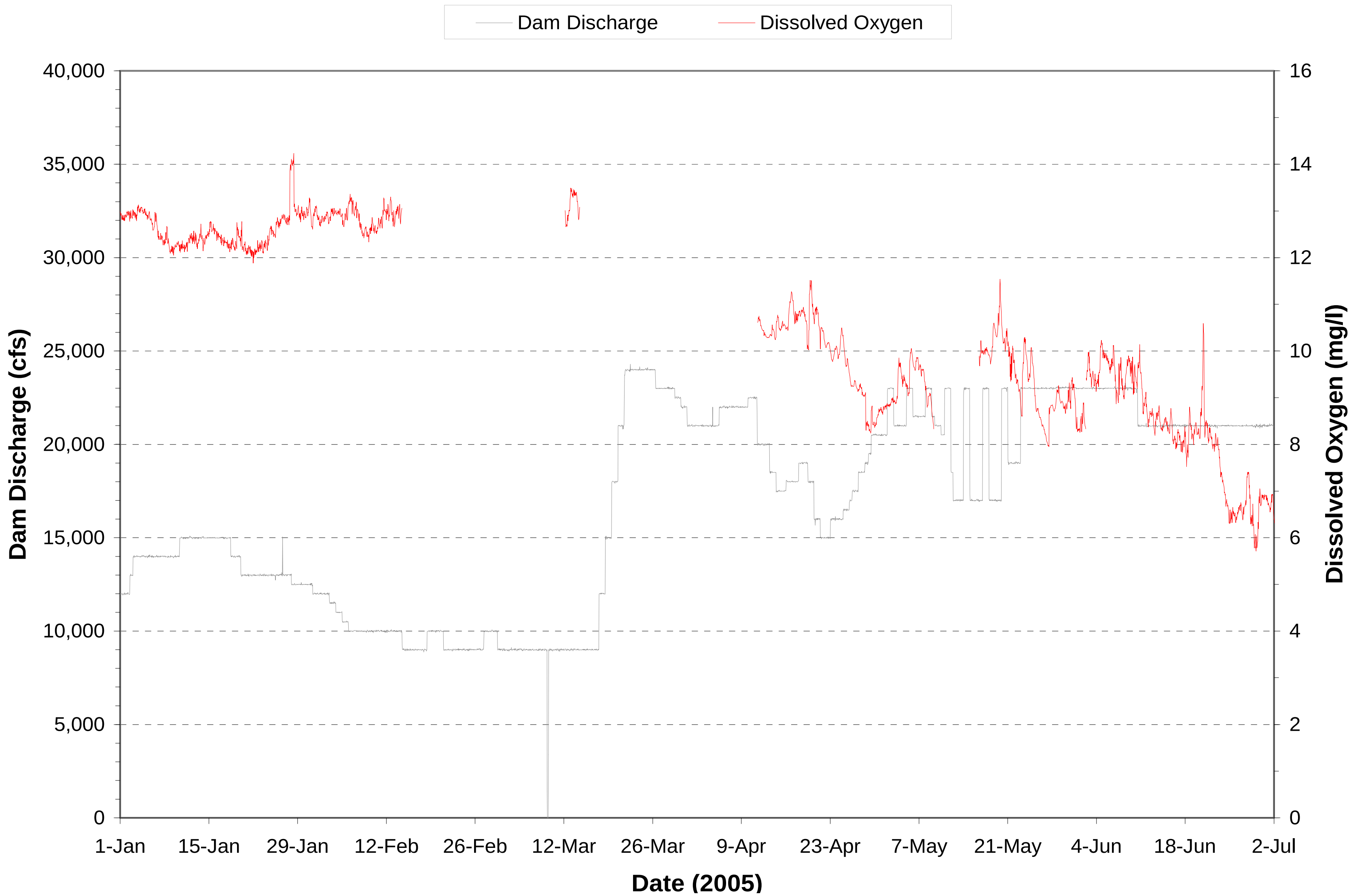


Plate 359. Hourly discharge and dissolved oxygen monitored at the Gavins Point powerplant on water discharged through the dam during the period January through June 2005.
Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.

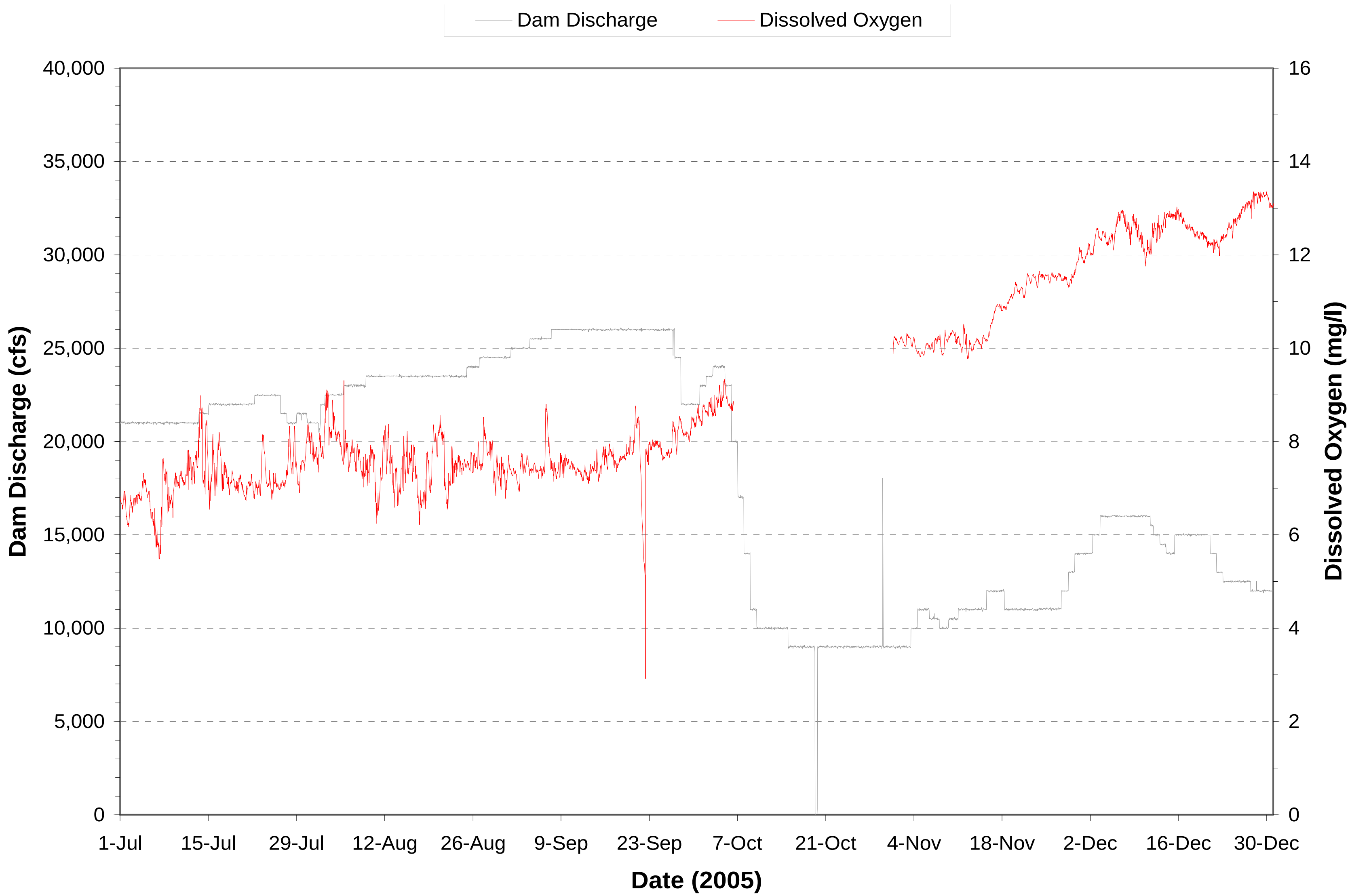


Plate 360. Hourly discharge and dissolved oxygen monitored at the Gavins Point powerplant on water discharged through the dam during the period July through December 2005.
Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.

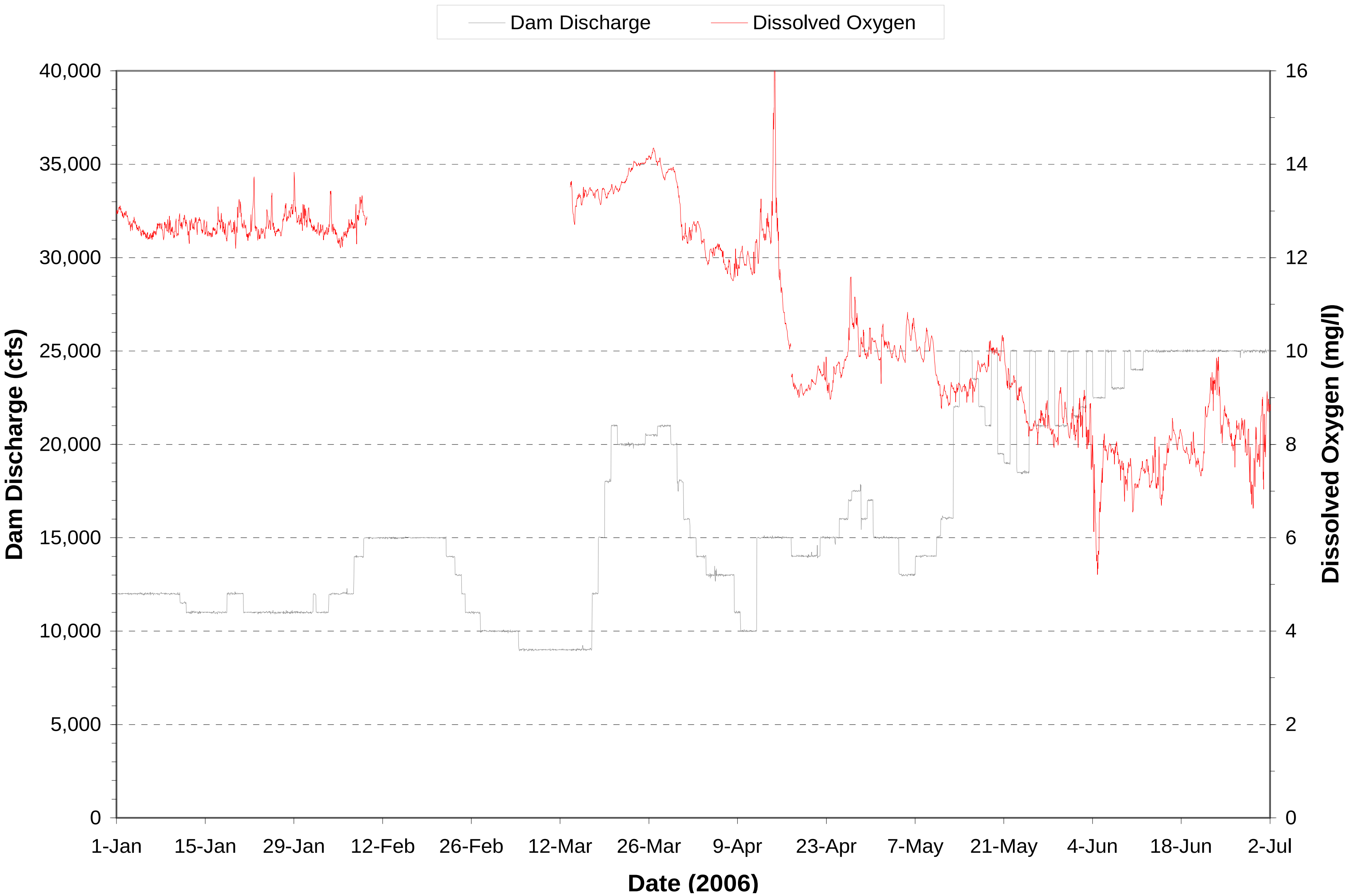


Plate 361. Hourly discharge and dissolved oxygen monitored at the Gavins Point powerplant on water discharged through the dam during the period January through June 2006.
Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.

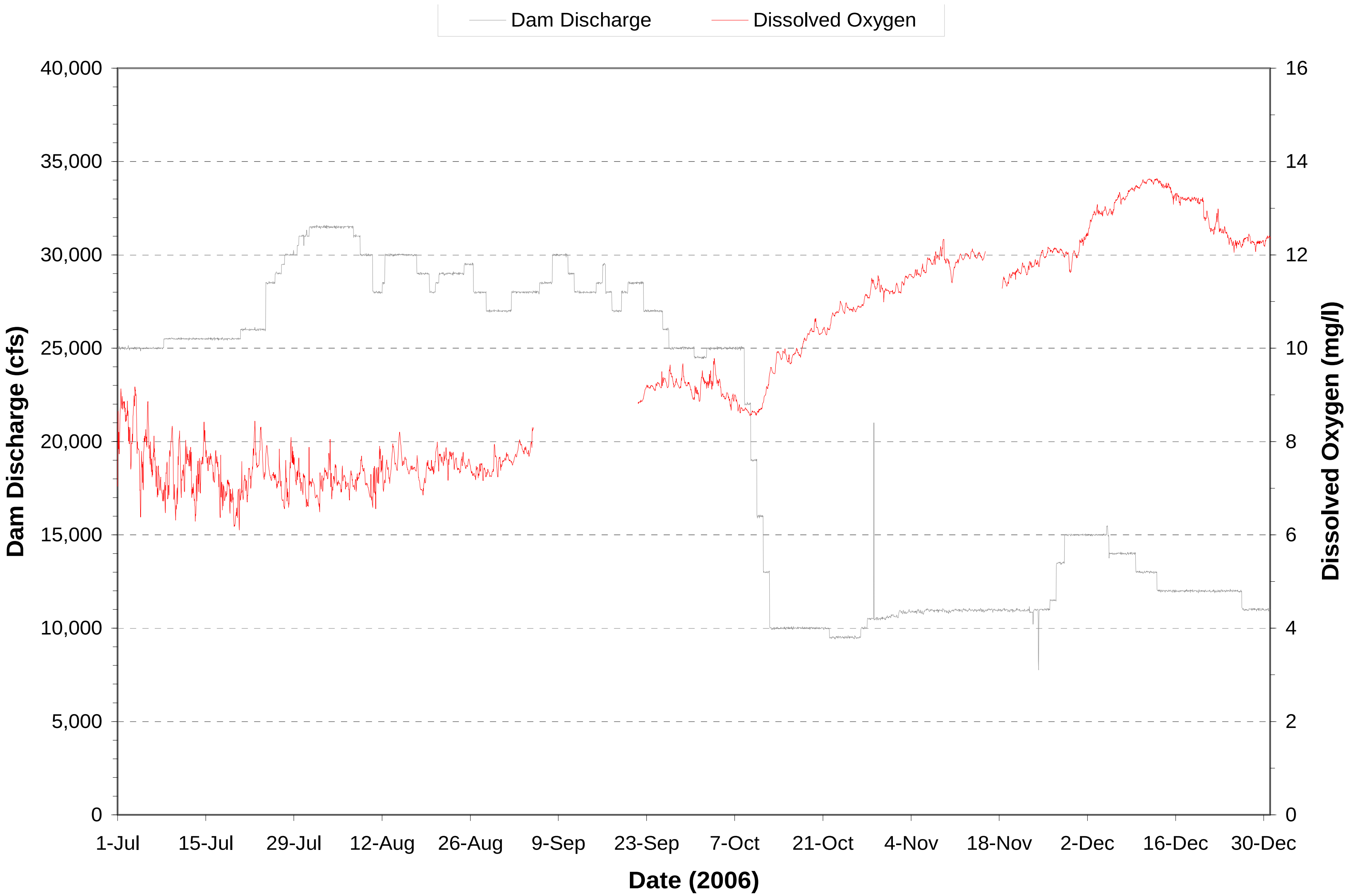


Plate 362. Hourly discharge and dissolved oxygen monitored at the Gavins Point powerplant on water discharged through the dam during the period July through December 2006.
Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.

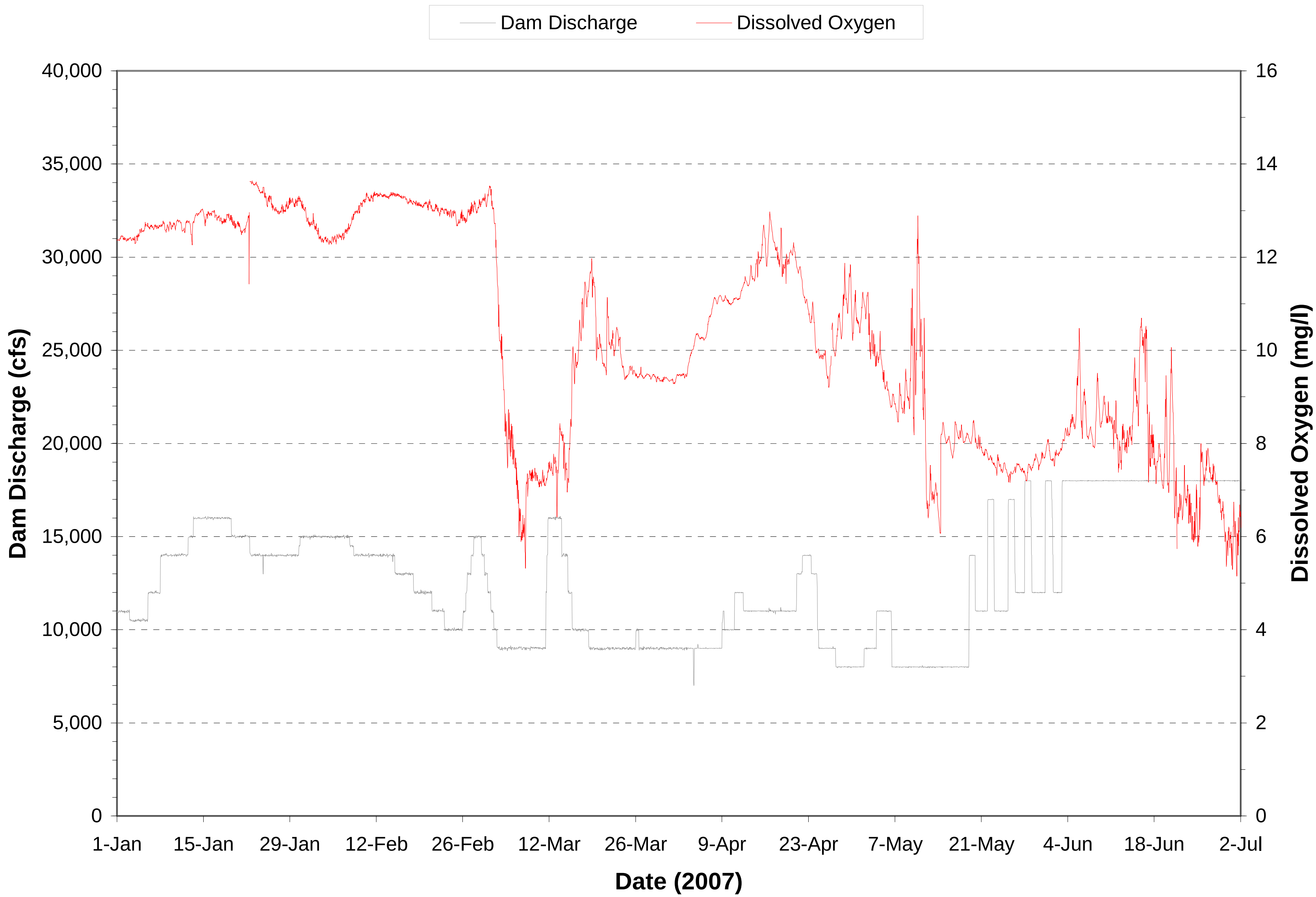


Plate 363. Hourly discharge and dissolved oxygen monitored at the Gavins Point powerplant on water discharged through the dam during the period January through June 2007.

Plate 364. Hourly discharge and dissolved oxygen monitored at the Gavins Point powerplant on water discharged through the dam during the period July through December 2007.
Note: Gaps in dissolved oxygen plot represents periods when monitoring equipment was not operational.

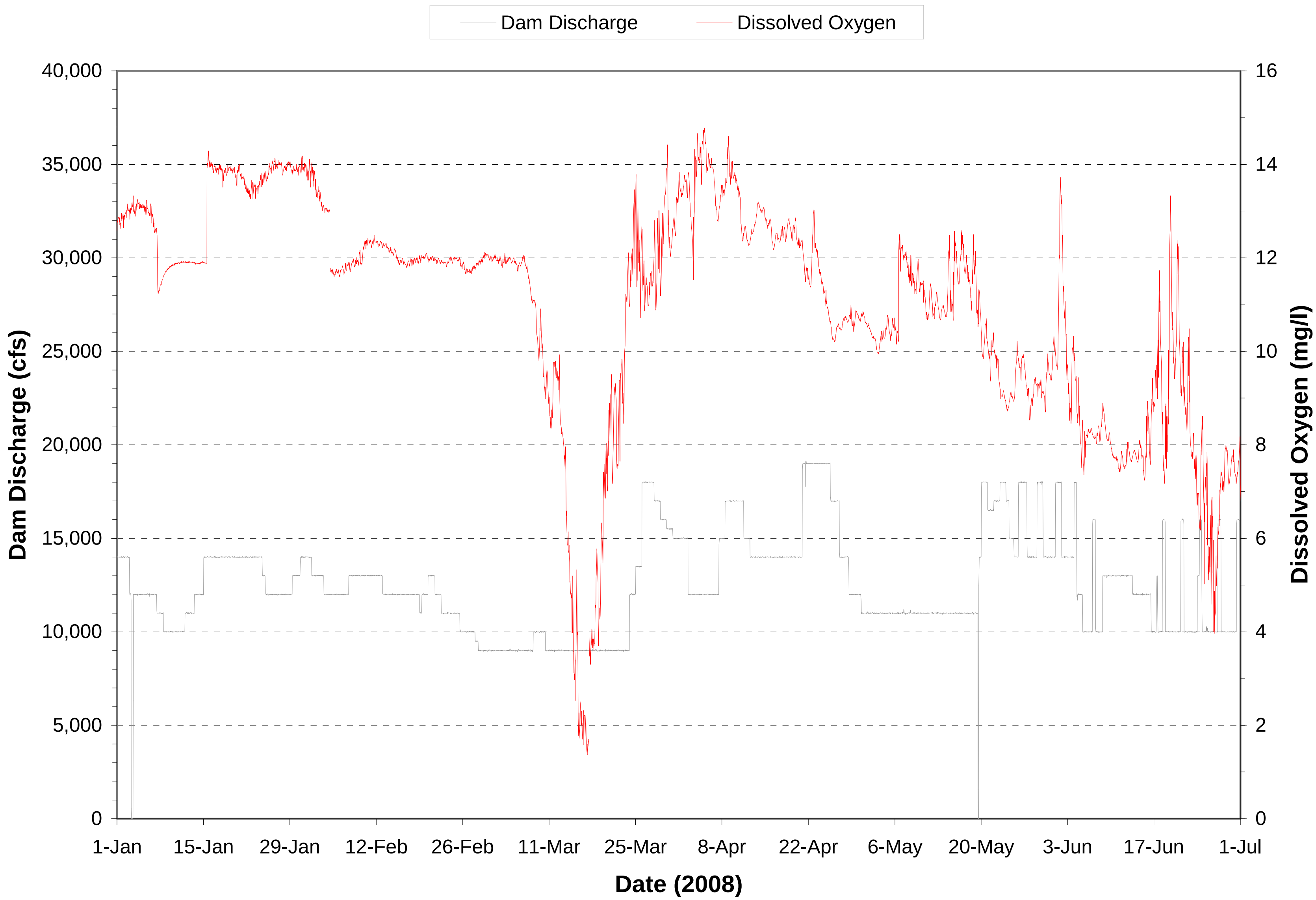


Plate 365. Hourly discharge and dissolved oxygen monitored at the Gavins Point powerplant on water discharged through the dam during the period January through June 2008.

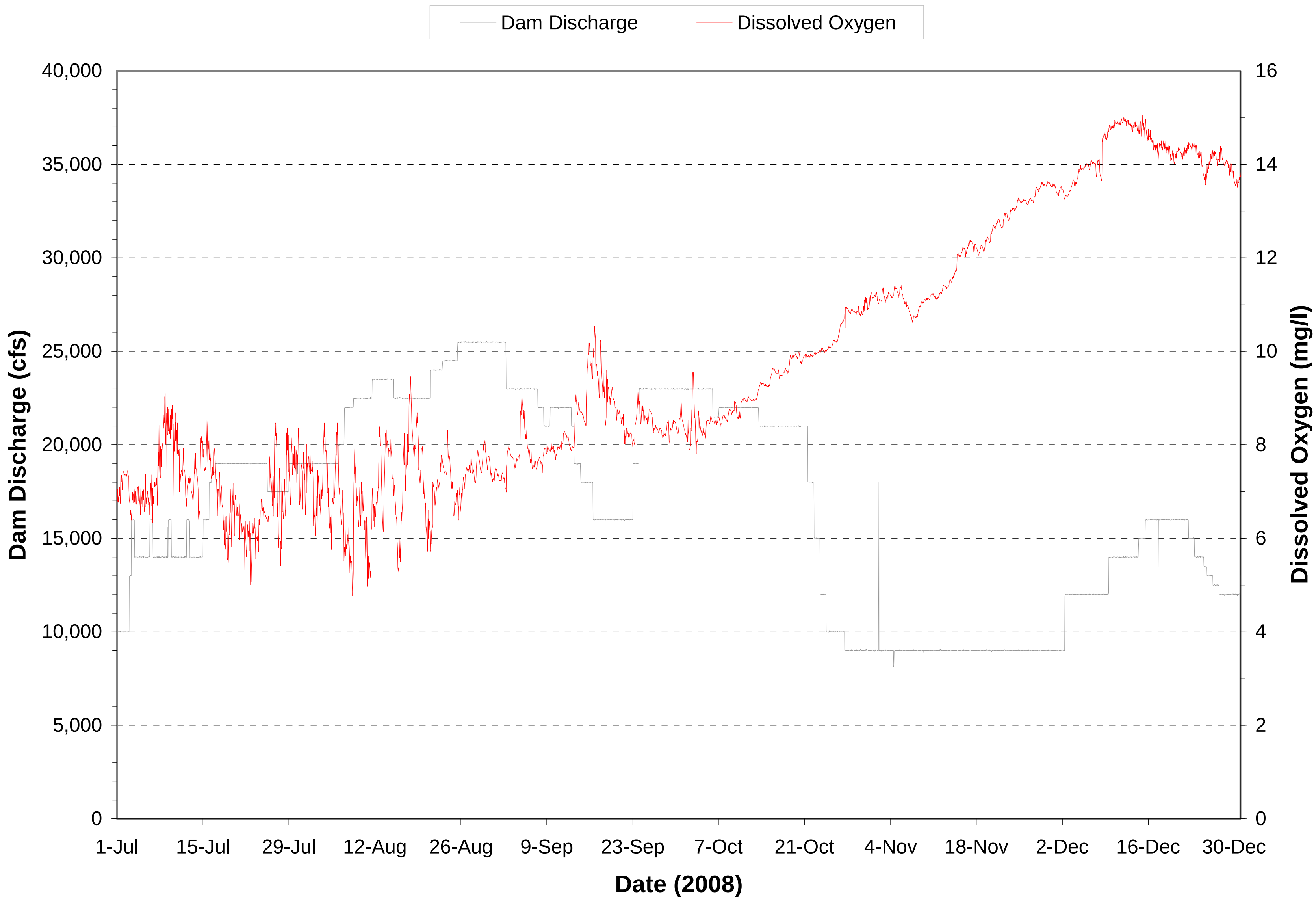


Plate 366. Hourly discharge and dissolved oxygen monitored at the Gavins Point powerplant on water discharged through the dam during the period July through December 2008.

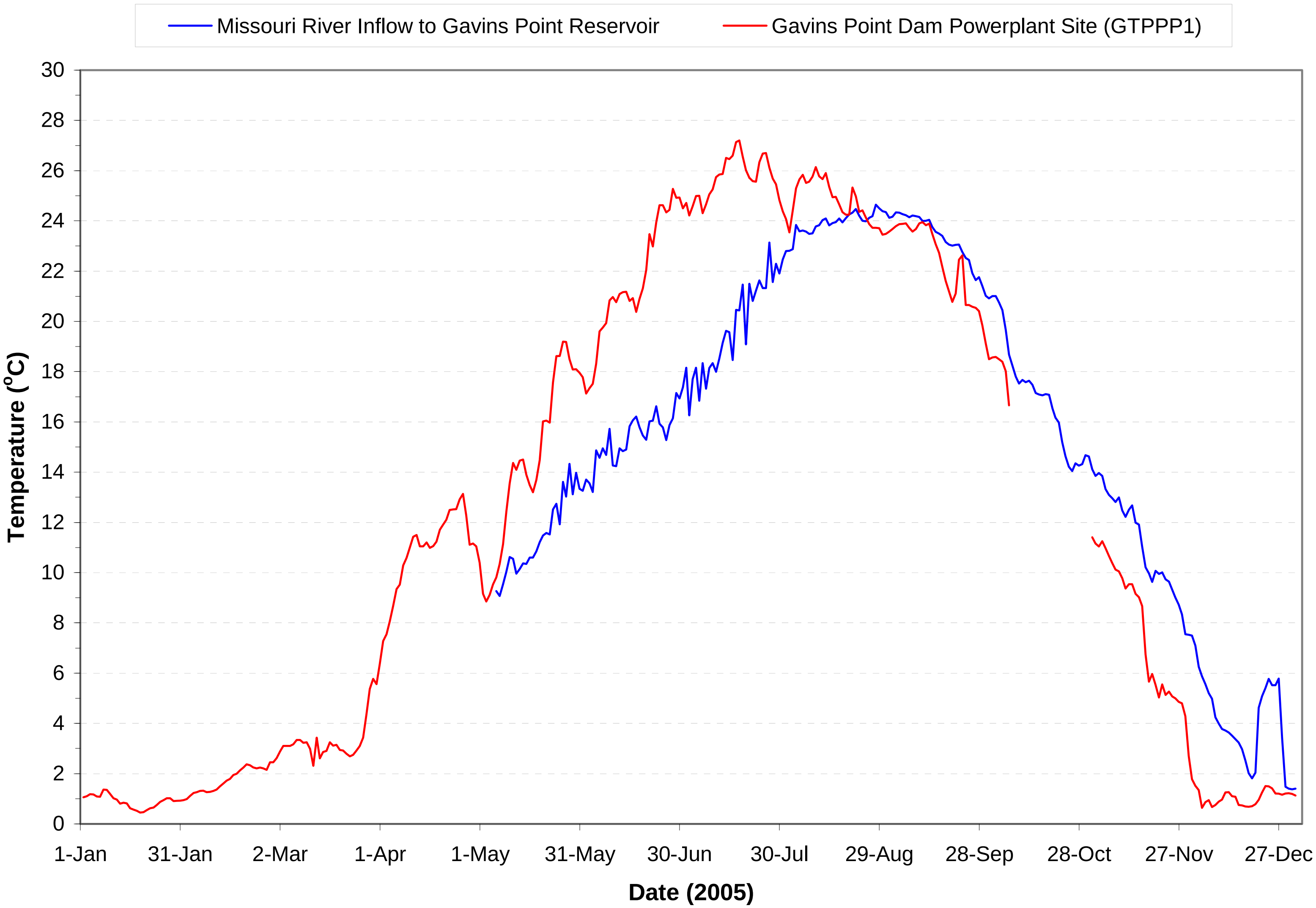


Plate 367. Mean daily water temperatures monitored at the Gavins Point Powerplant (i.e., site GTPPP1) and estimated for the Missouri River inflow to Gavins Point Reservoir during 2005.
Note: Gaps in temperature plots are periods when monitoring equipment was not operational.

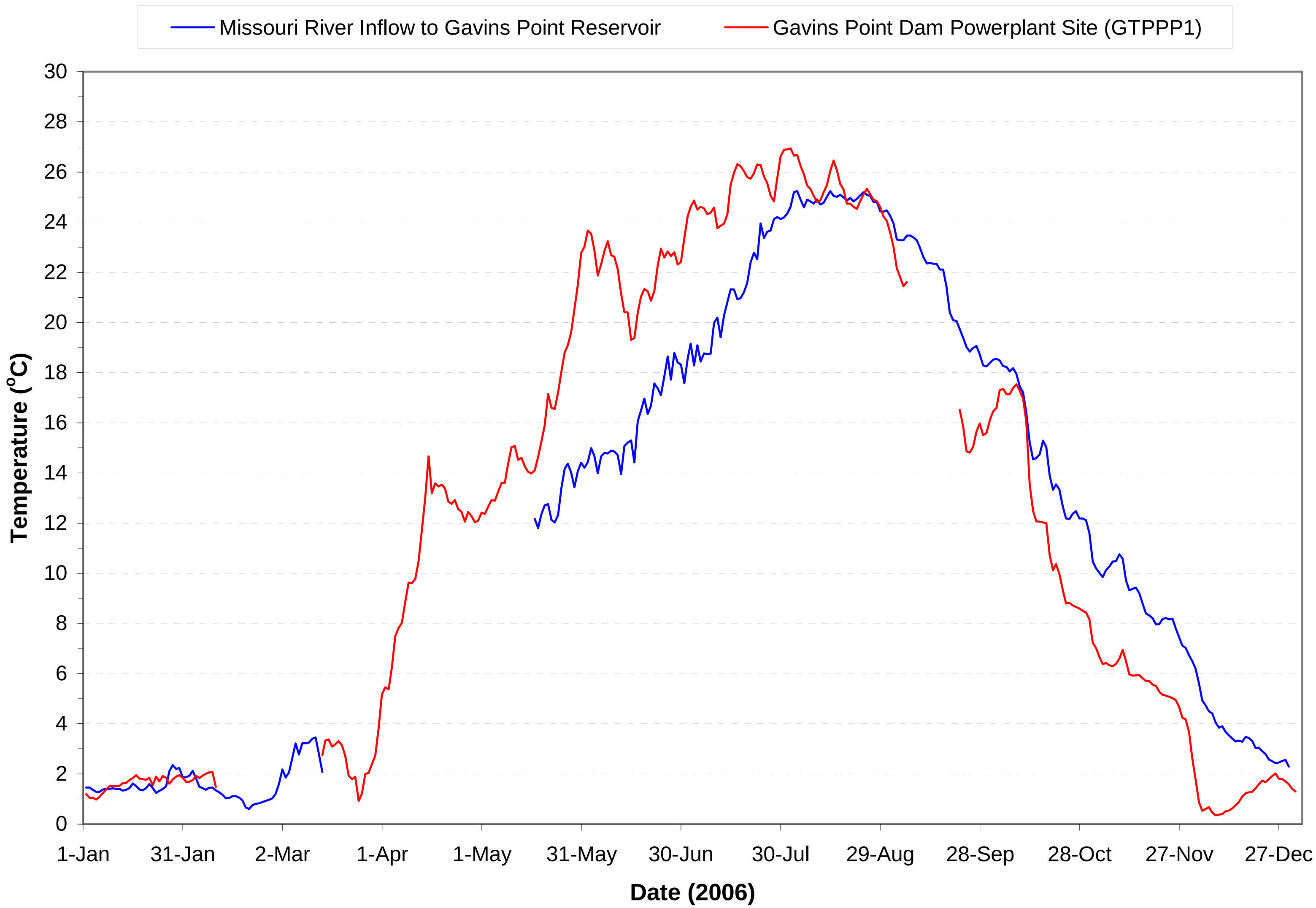


Plate 368. Mean daily water temperatures monitored at the Gavins Point Powerplant (i.e., site GTPPP1) and estimated for the Missouri River inflow to Gavins Point Reservoir during 2006.
Note: Gaps in temperature plots are periods when monitoring equipment was not operational.

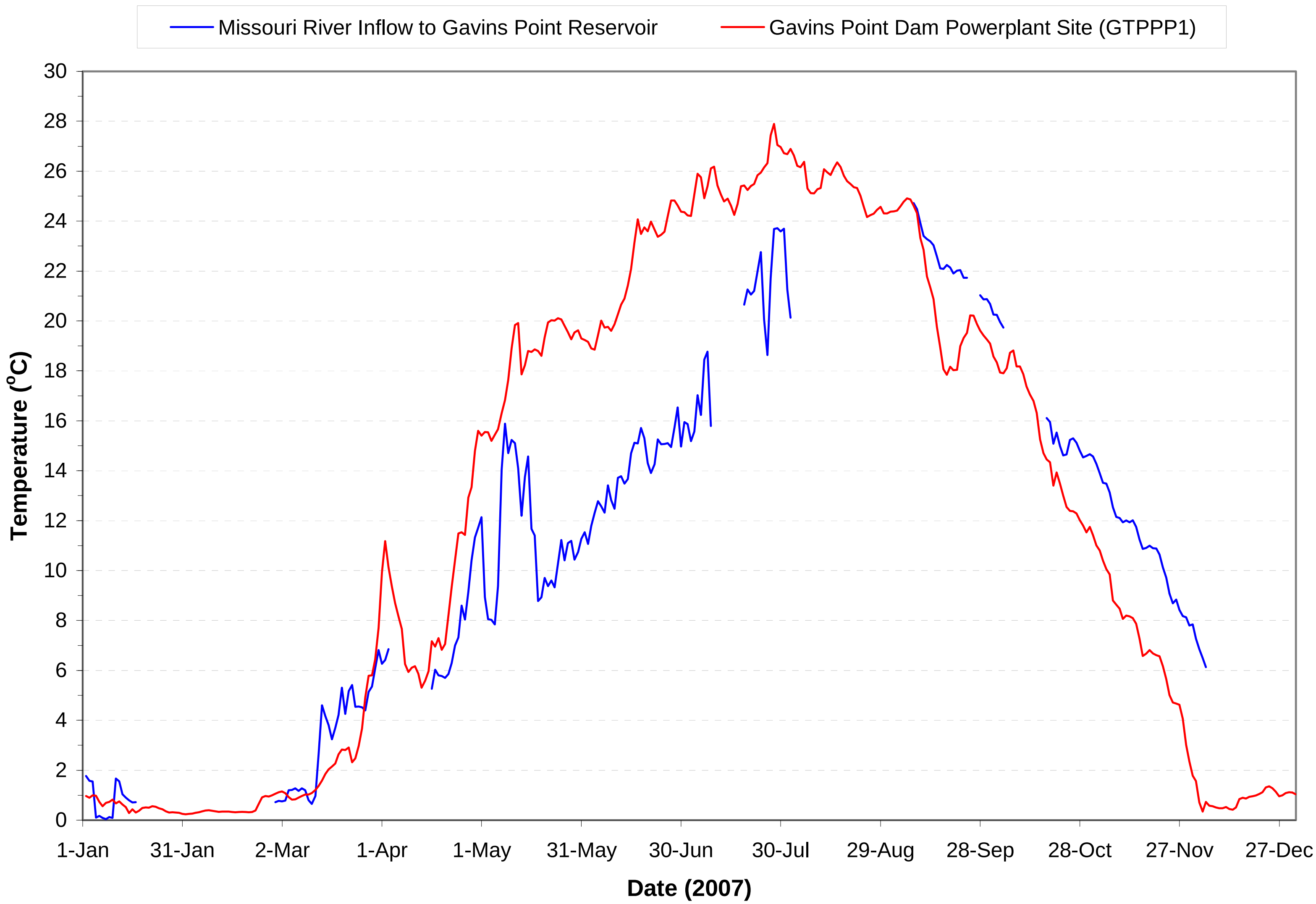


Plate 369. Mean daily water temperatures monitored at the Gavins Point Powerplant (i.e., site GTPPP1) and estimated for the Missouri River inflow to Gavins Point Reservoir during 2007.
Note: Gaps in temperature plots are periods when monitoring equipment was not operational.

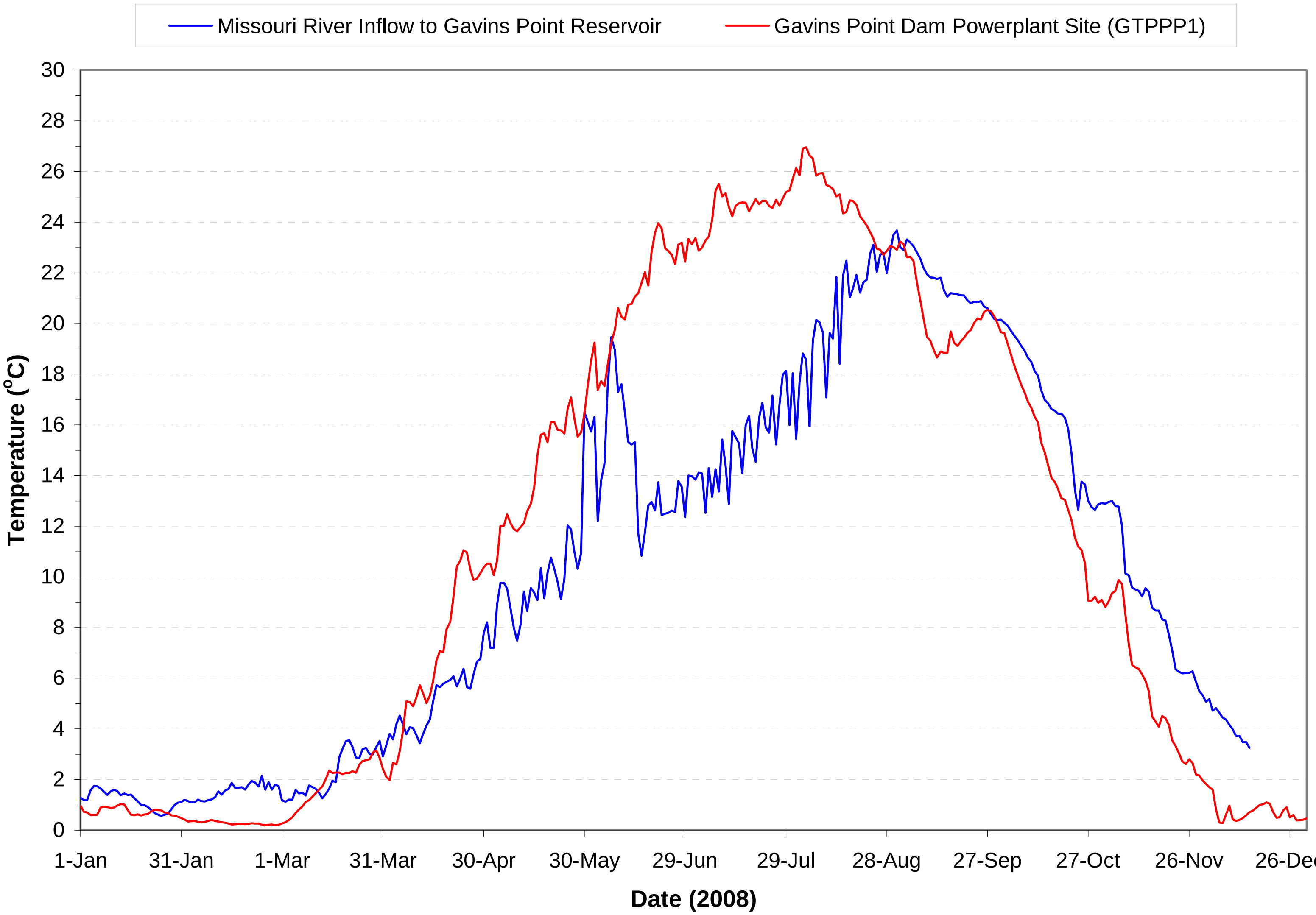


Plate 370. Mean daily water temperatures monitored at the Gavins Point Powerplant (i.e., site GTPPP1) and estimated for the Missouri River inflow to Gavins Point Reservoir during 2008.
Note: Gaps in temperature plots are periods when monitoring equipment was not operational.

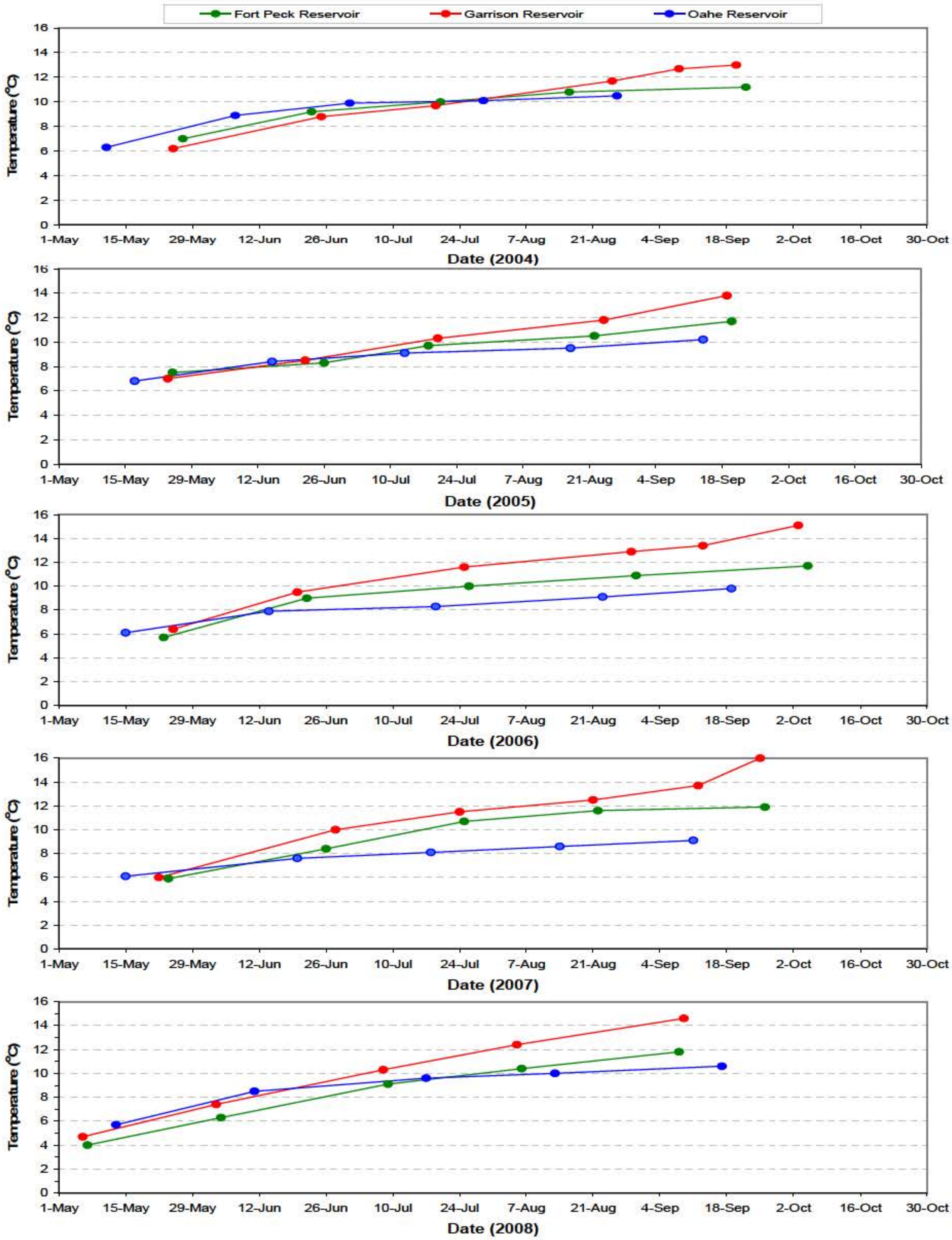


Plate 371. Near-bottom water temperatures measured at near-dam, deepwater locations in Fort Peck, Garrison, and Oahe Reservoirs during the 5-year period 2004 through 2008.

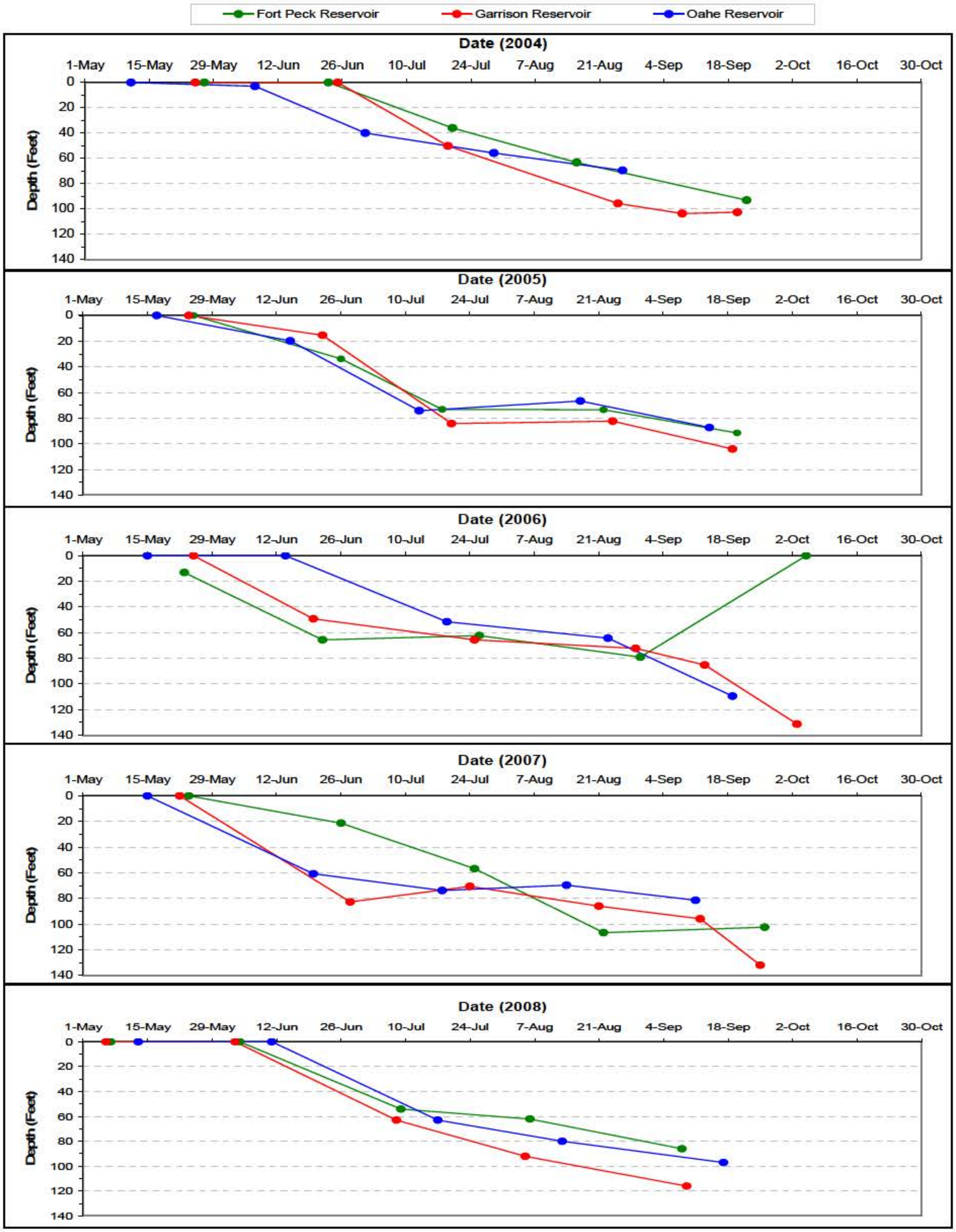


Plate 372. Depth to 15°C water temperature measured at near-dam, deepwater locations in Fort Peck, Garrison, and Oahe Reservoirs for the 5-year period 2004 through 2008.

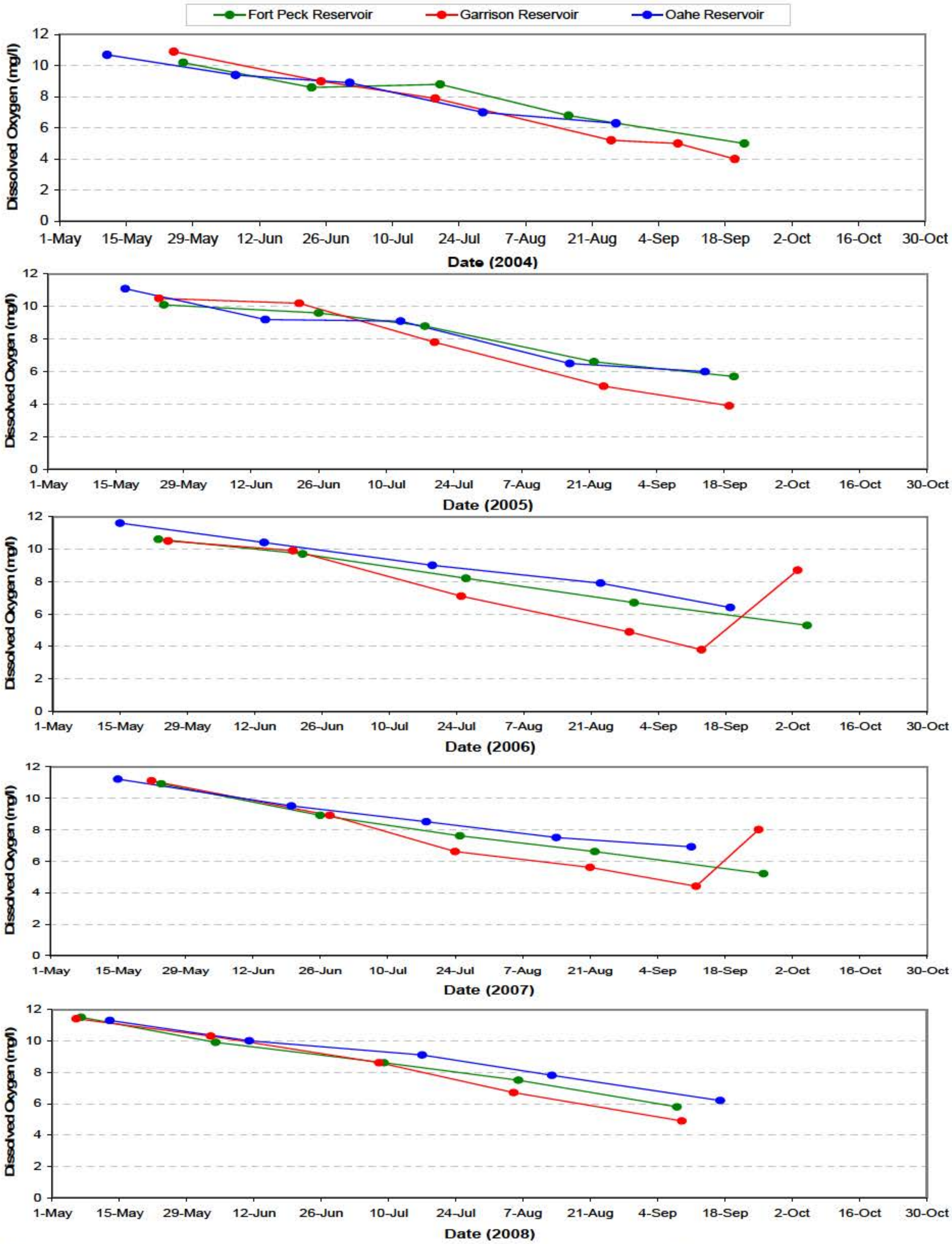


Plate 373. Near-bottom dissolved oxygen concentrations measured at near-dam, deepwater locations in Fort Peck, Garrison, and Oahe Reservoirs during the 5-year period 2004 through 2008.

Plate 374. Summary of water quality conditions monitored in the Missouri River at the Gavins Point Dam tailwaters (i.e., site GPTRRTW1) during the 5-year period 2004 through 2008.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit(A)	No. of Obs.	Mean(B)	Median	Min.	Max.	State WQS Criteria(C)	No. of WQS Exceedences	Percent WQS Exceedence
Streamflow (cfs)	1	85	18,344	19,013	8,000	30,963	-----	-----	-----
Water Temperature (C)	0.1	84	14.4	15.8	0.0	27	27(1,2,6), 29(1,2,6)	0	0%
Dissolved Oxygen (mg/l)	0.1	82	9.9	9.5	5.9	15.1	5(1,7)	0	0%
Dissolved Oxygen (% Sat.)	0.1	83	95.9	95.6	60.5	117.8	-----	-----	-----
Specific Conductance (umho/cm)	1	84	651	655	466	753	2,000(4)	0	0%
pH (S.U.)	0.1	82	8.3	8.3	7.6	8.8	6 5(1,3,7), 9.0(1,3,6), 9.5(5,6)	0	0%
Oxidation-Reduction Potential	1	28	380	369	308	472	-----	-----	-----
Alkalinity, Total (mg/l)	7	81	165	162	130	222	-----	0	0%
Ammonia, Total (mg/l)	0.02	81	-----	0.06	n.d.	0.56	4.7 (1,6,9), 1.4 (1,8,9)	0	0%
Carbon, Total Organic (mg/l)	0.05	79	3.4	3.2	2.3	7.8	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	81	10	9	n.d.	23	-----	-----	-----
Chloride (mg/l)	1	81	10	10	4	29	175(1,6), 100(1,8), 438(3,6), 250(3,8)	0	0%
Dissolved Solids, Total (mg/l)	5	46	452	460	350	510	1,750(3,6), 1,000(3,8), 3,500(5,6), 2,000(5,8)	1(6)	3%(6)
Hardness, Total (mg/l)	0.4	16	220	222	179	236	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	81	0.6	0.4	n.d.	1.8	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	80	-----	0.03	n.d.	0.60	10(3,6), 100(4,6)	0	0%
Phosphorus, Total (mg/l)	0.02	80	0.07	0.04	n.d.	1.10	-----	-----	-----
Suspended Solids, Total (mg/l)	4	81	10	9	n.d.	68	158(1,5), 90(1,8)	0	0%
Turbidity (NTU)	1	84	23	19	n.d.	76	-----	-----	-----
Aluminum, Dissolved (mg/l)	25	7	-----	n.d.	n.d.	50	750(10), 87(11), 200(12)	0	0%
Antimony, Dissolved (ug/l)	0.5	7	-----	n.d.	n.d.	1.0	88(10), 30(11), 6(12)	0	0%
Arsenic, Dissolved (ug/l)	1	19	-----	n.d.	n.d.	3	340(10), 16.7(11), 10(12)	0	0%
Barium, Dissolved (ug/l)	5	7	53	49	46	65	2,000(11)	0	0%
Beryllium, Dissolved (ug/l)	2	8	-----	n.d.	n.d.	n.d.	130(10), 5.3(11), 4(12)	0	0%
Cadmium, Dissolved (ug/l)	0.5	19	-----	n.d.	n.d.	n.d.	13(10), 0.43(11), 5(12)	0	0%
Chromium, Dissolved (ug/l)	10	19	-----	n.d.	n.d.	n.d.	1,138(10), 148(11), 100(12)	0	0%
Copper, Dissolved (ug/l)	2	18	-----	n.d.	n.d.	21	28(10), 18(11), 1,000(12)	0, 1, 0	0%, 6%, 0%
Lead, Dissolved (ug/l)	2	19	-----	n.d.	n.d.	n.d.	152(10), 5 9(11), 15(12)	0	0%
Mercury, Dissolved (ug/l)	0.02	18	-----	n.d.	n.d.	n.d.	1.4(10)	0	0%
Mercury, Total (ug/l)	0.02	18	-----	n.d.	n.d.	n.d.	0.77(11), 2(12)	0	0%
Nickel, Dissolved (ug/l)	10	19	-----	n.d.	n.d.	n.d.	919(10), 102(11), 100(12)	0	0%
Selenium, Total (ug/l)	4	19	-----	n.d.	n.d.	4	20(4,10), 5(11), 50(12)	0	0%
Silver, Dissolved (ug/l)	1	19	-----	n.d.	n.d.	n.d.	14(10), 100(12)	0	0%
Thallium, Dissolved (ug/l)	0.5	7	-----	n.d.	n.d.	n.d.	1,400(10), 6.3(11), 2(12)	0	0%
Zinc, Dissolved (ug/l)	10	19	-----	n.d.	n.d.	16	230(10,11), 5,000(12)	0	0%
Acetochlor, Total (ug/l)(D)	0.05	9	-----	n.d.	n.d.	0.40	-----	-----	-----
Alachlor, Total (ug/l)(D)	0.05	61	-----	n.d.	n.d.	0.07	760(10), 76(11), 2(12)	0	0%
Atrazine, Total (ug/l)(D)	0.05	70	-----	n.d.	n.d.	0.30	330(10), 12(11), 3(12)	0	0%
Metolachlor, Total (ug/l)(D)	0.05	70	-----	n.d.	n.d.	0.10	390(10), 100(11)	0	0%
Pesticide Scan (ug/l)(E)	0.05						-----	-----	-----
Atrazine, Total (ug/l)		13	-----	n.d.	n.d.	0.20	330(2), 12(3), 3(4)	0	0%

n.d. = Not detected.

(A) Detection limits given for the parameters Stream Flow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for the protection of Warmwater Permanent Fish Life Propagation Waters (South Dakota) or Class I Warmwater Aquatic Life (Nebraska).
- (2) South Dakota's temperature criterion is 27 C and Nebraska's is 29 C.
- (3) Criteria for the protection of domestic water supply waters.
- (4) Criteria for the protection of agricultural water supply waters.
- (5) Criteria for the protection of commerce and industry waters.
- (6) Daily maximum criterion (monitoring results directly comparable to criterion).
- (7) Daily minimum criterion (monitoring results directly comparable to criterion).
- (8) 30-day average criterion (monitoring results not directly comparable to criterion).
- (9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (10) Acute (CMC) criterion for the protection of freshwater aquatic life.
- (11) Chronic (CCC) criterion for the protection of freshwater aquatic life.
- (12) Criterion for the protection of human health.

Note: Some of South Dakota's and Nebraska's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

(D) Immunoassay analysis.

(E) The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, cycloate, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, isopropalin, metolachlor, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, phorate, profluralin, prometon, propachlor, propazine, simazine, terbufos, triallate, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

Plate 375. Summary of water quality conditions monitored in the Missouri River near Maskell, Nebraska (i.e., site MORRR0774) during the 5-year period 2004 through 2008.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit[A]	No. of Obs.	Mean[B]	Median	Min.	Max.	State WQS Criteria[C]	No. of WQS Exceedences	Percent WQS Exceedence
Streamflow (cfs)	1	74	20,479	22,007	9,161	31,082	-----	-----	-----
Water Temperature (C)	0.1	74	16.6	18.9	0.1	29.1	27[1,2,6], 29[1,2,6]	3, 1	4%, 1%
Dissolved Oxygen (mg/l)	0.1	73	9.7	8.9	6.0	14.2	5[1,7]	0	0%
Dissolved Oxygen (% Sat.)	0.1	73	99.7	99.4	68.7	121.0	-----	-----	-----
Specific Conductance (umho/cm)	1	74	666	667	471	780	2,000[4]	0	0%
pH (S.U.)	0.1	72	8.4	8.4	7.7	8.8	6 5[1,3,7], 9.0[1,3,6], 9.5[5,6]	0	0%
Oxidation-Reduction Potential	1	21	377	365	297	481	-----	-----	-----
Alkalinity, Total (mg/l)	7	76	169	168	140	221	-----	0	0%
Ammonia, Total (mg/l)	0.02	76	-----	0.06	n.d.	0.54	3.9 [1,6,9], 0.97 [1,8,9]	0	0%
Carbon, Total Organic (mg/l)	0.05	74	3.6	3.3	1.7	8.1	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	76	12	11	n.d.	27	-----	-----	-----
Chloride (mg/l)	1	76	12	10	4	45	175[1,6], 100[1,8], 438[3,6], 250[3,8]	0	0%
Dissolved Solids, Total (mg/l)	5	41	473	470	416	540	1,750[3,6], 1,000[3,8], 3,500[5,6], 2,000[5,8]	1[6]	3%[6]
Hardness, Total (mg/l)	0.4	18	240	236	216	342	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	76	0.6	0.5	n.d.	2.0	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	76	-----	0.07	n.d.	1.30	10[3,6], 100[4,6]	0	0%
Phosphorus, Total (mg/l)	0.02	75	0.08	0.06	n.d.	0.40	-----	-----	-----
Suspended Solids, Total (mg/l)	4	76	33	22	n.d.	204	158[1,5], 90[1,8]	3, 6	4%, 8%
Turbidity (NTU)	1	73	36	27	3	236	-----	-----	-----
Aluminum, Dissolved (mg/l)	25	7	-----	n.d.	n.d.	60	750[10], 87[11], 200[12]	0	0%
Antimony, Dissolved (ug/l)	0.5	7	-----	n.d.	n.d.	1.0	88[10], 30[11], 6[12]	0	0%
Arsenic, Dissolved (ug/l)	1	18	-----	n.d.	n.d.	3.0	340[10], 16.7[11], 10[12]	0	0%
Barium, Dissolved (ug/l)	5	7	57	57	48	73	2,000[11]	0	0%
Beryllium, Dissolved (ug/l)	2	8	-----	n.d.	n.d.	n.d.	130[10], 5.3[11], 4[12]	0	0%
Cadmium, Dissolved (ug/l)	0.5	18	-----	n.d.	n.d.	n.d.	14[10], 0.45[11], 5[12]	0	0%
Chromium, Dissolved (ug/l)	10	18	-----	n.d.	n.d.	n.d.	1,196[10], 156[11], 100[12]	0	0%
Copper, Dissolved (ug/l)	2	17	-----	n.d.	n.d.	3.	30[10], 19[11], 1,000[12]	0, 1, 0	0%, 6%, 0%
Lead, Dissolved (ug/l)	2	18	-----	n.d.	n.d.	n.d.	162[10], 6 3[11], 15[12]	0	0%
Mercury, Dissolved (ug/l)	0.02	17	-----	n.d.	n.d.	n.d.	1.4[10]	0	0%
Mercury, Total (ug/l)	0.02	17	-----	n.d.	n.d.	n.d.	0.77[11], 2[12]	0	0%
Nickel, Dissolved (ug/l)	10	18	-----	n.d.	n.d.	n.d.	968[10], 108[11], 100[12]	0	0%
Selenium, Total (ug/l)	4	18	-----	n.d.	n.d.	4	20[4,10], 5[11], 50[12]	0	0%
Silver, Dissolved (ug/l)	1	18	-----	n.d.	n.d.	n.d.	15[10], 100[12]	0	0%
Thallium, Dissolved (ug/l)	0.5	7	-----	n.d.	n.d.	n.d.	1,400[10], 6.3[11], 2[12]	0	0%
Zinc, Dissolved (ug/l)	10	17	-----	n.d.	n.d.	97	243[10,11], 5,000[12]	0	0%
Acetochlor, Total (ug/l)[D]	0.05	8	-----	n.d.	n.d.	0.50	-----	-----	-----
Alachlor, Total (ug/l)[D]	0.05	59	-----	n.d.	n.d.	0.13	760[10], 76[11], 2[12]	0	0%
Atrazine, Total (ug/l)[D]	0.05	67	-----	n.d.	n.d.	3.70	330[10], 12[11], 3[12]	0, 0, 1	0%, 0%, 1%
Metolachlor, Total (ug/l)[D]	0.05	67	-----	n.d.	n.d.	0.50	390[10], 100[11]	0	0%
Pesticide Scan (ug/l)[E]	0.05						-----	-----	-----
Acetochlor, Total (ug/l)		11	-----	n.d.	n.d.	0.30	-----	-----	-----
Atrazine, Total (ug/l)		11	-----	n.d.	n.d.	0.20	330[2], 12[3], 3[4]	0	0%
Profluralin, Total (ug/l)		4	-----	n.d.	n.d.	0.17	-----	-----	-----

n.d. = Not detected.

(A) Detection limits given for the parameters Stream Flow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for the protection of Warmwater Permanent Fish Life Propagation Waters (South Dakota) or Class I Warmwater Aquatic Life (Nebraska).
- (2) South Dakota's temperature criterion is 27 C and Nebraska's is 29 C.
- (3) Criteria for the protection of domestic water supply waters.
- (4) Criteria for the protection of agricultural water supply waters.
- (5) Criteria for the protection of commerce and industry waters.
- (6) Daily maximum criterion (monitoring results directly comparable to criterion).
- (7) Daily minimum criterion (monitoring results directly comparable to criterion).
- (8) 30-day average criterion (monitoring results not directly comparable to criterion).
- (9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (10) Acute (CMC) criterion for the protection of freshwater aquatic life.
- (11) Chronic (CCC) criterion for the protection of freshwater aquatic life.
- (12) Criterion for the protection of human health.

Note: Some of South Dakota's and Nebraska's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

(D) Immunoassay analysis.

(E) The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, cycloate, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, isopropalin, metolachlor, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, phorate, profluralin, prometon, propachlor, propazine, simazine, terbufos, triallate, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

Plate 376. Summary of water quality conditions monitored in the Missouri River near Ponca, Nebraska (i.e., site MORRR0753) during the 5-year period 2004 through 2008.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit[A]	No. of Obs.	Mean[B]	Median	Min.	Max.	State WQS Criteria[C]	No. of WQS Exceedences	Percent WQS Exceedence
Streamflow (cfs)	1	74	20,856	22,669	9,247	31,661	-----	-----	-----
Water Temperature (C)	0.1	74	16.6	19.4	0.2	29.5	27[1,2,6], 29[1,2,6]	4, 1	5%, 1%
Dissolved Oxygen (mg/l)	0.1	73	9.6	9.0	7.3	14.3	5[1,7]	0	0%
Dissolved Oxygen (% Sat.)	0.1	73	99.7	99.5	60.8	125.2	-----	-----	-----
Specific Conductance (umho/cm)	1	74	684	683	469	894	2,000[4]	0	0%
pH (S.U.)	0.1	72	8.4	8.4	7.7	8.8	6 5[1,3,7], 9.0[1,3,6], 9.5[5,6]	0	0%
Oxidation-Reduction Potential	1	25	380	385	288	477	-----	-----	-----
Alkalinity, Total (mg/l)	7	74	169	170	127	218	-----	0	0%
Ammonia, Total (mg/l)	0.02	74	-----	0.05	n.d.	0.42	3.9 [1,6,9], 0.94 [1,8,9]	0	0%
Carbon, Total Organic (mg/l)	0.05	71	3.9	3.5	2.4	8.9	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	74	12	11	n.d.	45	-----	-----	-----
Chloride (mg/l)	1	74	11	11	4	26	175[1,6], 100[1,8], 438[3,6], 250[3,8]	0	0%
Dissolved Solids, Total (mg/l)	5	42	502	495	316	626	1,750[3,6], 1,000[3,8], 3,500[5,6], 2,000[5,8]	1[6]	3%[6]
Hardness, Total (mg/l)	0.4	16	243	243	225	279	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	74	0.7	0.5	0.2	4.3	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	74	-----	0.03	n.d.	1.10	10[3,6], 100[4,6]	0	0%
Phosphorus, Total (mg/l)	0.02	73	0.12	0.07	n.d.	0.60	-----	-----	-----
Suspended Solids, Total (mg/l)	4	74	42	28	n.d.	352	158[1,5], 90[1,8]	4, 4	5%, 5%
Turbidity (NTU)	1	73	42	27	4	358	-----	-----	-----
Aluminum, Dissolved (mg/l)	25	5	-----	n.d.	n.d.	690	750[10], 87[11], 200[12]	0, 1, 1	0%, 20%, 20%
Antimony, Dissolved (ug/l)	0.5	6	-----	n.d.	n.d.	0.7	88[10], 30[11], 6[12]	0	0%
Arsenic, Dissolved (ug/l)	1	17	-----	n.d.	n.d.	3	340[10], 16.7[11], 10[12]	0	0%
Barium, Dissolved (ug/l)	5	6	59	59	48	66	2,000[11]	0	0%
Beryllium, Dissolved (ug/l)	2	7	-----	n.d.	n.d.	n.d.	130[10], 5.3[11], 4[12]	0	0%
Cadmium, Dissolved (ug/l)	0.5	17	-----	n.d.	n.d.	n.d.	14[10], 0.46[11], 5[12]	0	0%
Chromium, Dissolved (ug/l)	10	17	-----	n.d.	n.d.	n.d.	1,225[10], 159[11], 100[12]	0	0%
Copper, Dissolved (ug/l)	2	17	-----	n.d.	n.d.	24	31[10], 19[11], 1,000[12]	0, 1, 0	0%, 6%, 0%
Lead, Dissolved (ug/l)	2	17	-----	n.d.	n.d.	n.d.	167[10], 6 5[11], 15[12]	0	0%
Mercury, Dissolved (ug/l)	0.02	16	-----	n.d.	n.d.	n.d.	1.4[10]	0	0%
Mercury, Total (ug/l)	0.02	16	-----	n.d.	n.d.	n.d.	0.77[11], 2[12]	0	0%
Nickel, Dissolved (ug/l)	10	17	-----	n.d.	n.d.	n.d.	992[10], 110[11], 100[12]	0	0%
Selenium, Total (ug/l)	4	17	-----	n.d.	n.d.	4	20[4,10], 5[11], 50[12]	0	0%
Silver, Dissolved (ug/l)	1	16	-----	n.d.	n.d.	n.d.	16[10], 100[12]	0	0%
Thallium, Dissolved (ug/l)	0.5	6	-----	n.d.	n.d.	n.d.	1,400[10], 6.3[11], 2[12]	0	0%
Zinc, Dissolved (ug/l)	10	17	-----	n.d.	n.d.	64	249[10,11], 5,000[12]	0	0%
Acetochlor, Total (ug/l)[D]	0.05	8	-----	n.d.	n.d.	2.00	-----	-----	-----
Alachlor, Total (ug/l)[D]	0.05	57	-----	n.d.	n.d.	n.d.	760[10], 76[11], 2[12]	0	0%
Atrazine, Total (ug/l)[D]	0.05	65	----	n.d.	n.d.	1.00	330[10], 12[11], 3[12]	0	0%
Metolachlor, Total (ug/l)[D]	0.05	65	-----	n.d.	n.d.	1.30	390[10], 100[11]	0	0%
Pesticide Scan (ug/l)[E]	0.05						-----	-----	-----
Acetochlor, Total (ug/l)		12	-----	n.d.	n.d.	0.30	-----	-----	-----
Atrazine, Total (ug/l)		12	-----	n.d.	n.d.	0.40	330[2], 12[3], 3[4]	0	0%
Metolachlor, Total (ug/l)		12	-----	n.d.	n.d.	0.10	390[10], 100[11]	0	0%
Profluralin, Total (ug/l)		4	-----	n.d.	n.d.	0.12	-----	-----	-----

n.d. = Not detected.

(A) Detection limits given for the parameters Stream Flow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for the protection of Warmwater Permanent Fish Life Propagation Waters (South Dakota) or Class I Warmwater Aquatic Life (Nebraska).
- (2) South Dakota's temperature criterion is 27 C and Nebraska's is 29 C.
- (3) Criteria for the protection of domestic water supply waters.
- (4) Criteria for the protection of agricultural water supply waters.
- (5) Criteria for the protection of commerce and industry waters.
- (6) Daily maximum criterion (monitoring results directly comparable to criterion).
- (7) Daily minimum criterion (monitoring results directly comparable to criterion).
- (8) 30-day average criterion (monitoring results not directly comparable to criterion).
- (9) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (10) Acute (CMC) criterion for the protection of freshwater aquatic life.
- (11) Chronic (CCC) criterion for the protection of freshwater aquatic life.
- (12) Criterion for the protection of human health.

Note: Some of South Dakota's and Nebraska's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

(D) Immunoassay analysis.

(E) The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, cycloate, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, isopropalin, metolachlor, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, phorate, profluralin, prometon, propachlor, propazine, simazine, terbufos, triallate, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

Plate 377. Summary of water quality conditions monitored in the Missouri River at Decatur, Nebraska (i.e., site MORRR0691) during the 5-year period 2004 through 2008.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit(A)	No. of Obs.	Mean(B)	Median	Min.	Max.	State WQS Criteria(C)	No. of WQS Exceedences	Percent WQS Exceedence
Streamflow (cfs)	1	86	24,822	26,150	11,500	42,400	-----	-----	-----
Water Temperature (C)	0.1	82	16.0	16.5	0.0	29.8	32(1,5)	0	0%
Dissolved Oxygen (mg/l)	0.1	81	9.5	8.9	6.4	14.9	5(1,6)	0	0%
Dissolved Oxygen (% Sat.)	0.1	81	95.6	96.5	60.8	118.1	-----	-----	-----
Specific Conductance (umho/cm)	1	82	721	716	489	956	2,000(3)	0	0%
pH (S.U.)	0.1	80	8.2	8.3	7.2	8.9	6.5(1,6), 9.0(1,5)	0	0%
Oxidation-Reduction Potential	1	29	391	396	287	516	-----	-----	-----
Alkalinity, Total (mg/l)	7	81	183	186	125	222	-----	0	0%
Ammonia, Total (mg/l)	0.02	81	-----	0.09	n.d.	0.54	4.7 (1,5,8), 1.3 (1,7,8)	0	0%
Carbon, Total Organic (mg/l)	0.05	78	4.1	3.6	1.7	11.8	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	81	15	12	n.d.	76	-----	-----	-----
Chloride (mg/l)	1	81	15	14	8	24	250(2), 860(9), 230(10)	0	0%
Dissolved Solids, Total (mg/l)	5	45	525	516	338	790	500(2)	26(12)	58%(12)
Hardness, Total (mg/l)	0.4	19	278	270	240	381	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	81	1.0	0.8	0.3	5.0	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	80	1.14	0.95	n.d.	5.00	10(2,5), 100(3,5)	0	0%
Phosphorus, Total (mg/l)	0.02	80	0.19	0 13	n.d.	1.10	-----	-----	-----
Suspended Solids, Total (mg/l)	4	81	86	42	n.d.	580	-----	-----	-----
Turbidity (NTU)	1	81	66	41	4	374	-----	-----	-----
Aluminum, Dissolved (mg/l)	25	6	-----	n.d.	n.d.	n.d.	750(9), 87(10), 200(2)	0	0%
Antimony, Dissolved (ug/l)	0.5	7	-----	n.d.	n.d.	0.6	88(9), 30(10), 6(2)	0	0%
Arsenic, Dissolved (ug/l)	1	19	-----	n.d.	n.d.	4	340(9), 16.7(10,11), 10(2)	0	0%
Barium, Dissolved (ug/l)	5	7	66	63	53	83	2,000(2)	0	0%
Beryllium, Dissolved (ug/l)	2	8	-----	n.d.	n.d.	n.d.	130(5), 5.3(10), 4(2)	0	0%
Cadmium, Dissolved (ug/l)	0.5	19	-----	n.d.	n.d.	0.5	15(9), 0.49(10), 5(2)	0	0%
Chromium, Dissolved (ug/l)	10	19	-----	n.d.	n.d.	n.d.	1,335(9), 174(10), 100(2)	0	0%
Copper, Dissolved (ug/l)	2	19	-----	n.d.	n.d.	n.d.	34(9), 21(10), 1,000(2)	0	0%
Lead, Dissolved (ug/l)	2	19	-----	n.d.	n.d.	n.d.	187(9), 7.3(10)	0	0%
Mercury, Dissolved (ug/l)	0.02	18	-----	n.d.	n.d.	0.07	1.4(9)	0	0%
Mercury, Total (ug/l)	0.02	18	-----	n.d.	n.d.	n.d.	0.77(10), 2(2)	0	0%
Nickel, Dissolved (ug/l)	10	19	-----	n.d.	n.d.	n.d.	1,085(9), 121(10)	0	0%
Selenium, Total (ug/l)	4	19	-----	n.d.	n.d.	4	20(3,9), 5(10), 50(2)	0	0%
Silver, Dissolved (ug/l)	1	19	-----	n.d.	n.d.	n.d.	19(9), 100(2)	0	0%
Thallium, Dissolved (ug/l)	0.5	7	-----	n.d.	n.d.	n.d.	1,400(5), 6.3(10,11), 2(2)	0	0%
Zinc, Dissolved (ug/l)	10	19	-----	n.d.	n.d.	68	272(9,10), 5,000(2)	0	0%
Acetochlor, Total (ug/l)(D)	0.05	9	-----	n.d.	n.d.	1.40	-----	-----	-----
Alachlor, Total (ug/l)(D)	0.05	62	-----	n.d.	n.d.	0.20	760(9), 76(10), 2(2)	0	0%
Atrazine, Total (ug/l)(D)	0.05	71	-----	0.06	n.d.	2.05	330(9), 12(10), 3(2)	0	0%
Metolachlor, Total (ug/l)(D)	0.05	71	-----	n.d.	n.d.	2.50	390(9), 100(10)	0	0%
Pesticide Scan (ug/l)(E)	0.05						-----	-----	-----
Acetochlor, Total (ug/l)		11	-----	n.d.	n.d.	0.15			
Atrazine, Total (ug/l)		11	-----	n.d.	n.d.	0.80	330(9), 12(10), 3(2)	0	0%
Metolachlor, Total (ug/l)		11	-----	n.d.	n.d.	0.50	-----	-----	-----

n.d. = Not detected.

(A) Detection limits given for the parameters Stream Flow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- (1) Criteria for the protection of Class I Warmwater Aquatic Life (Nebraska).
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of agricultural water supply waters.
- (4) Criteria for the protection of commerce and industry waters.
- (5) Daily maximum criterion (monitoring results directly comparable to criterion).
- (6) Daily minimum criterion (monitoring results directly comparable to criterion).
- (7) 30-day average criterion (monitoring results not directly comparable to criterion).
- (8) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (9) Acute criterion for aquatic life.
- (10) Chronic criterion for aquatic life.
- (11) Criterion for the protection of human health.
- (12) Criterion for total dissolved solids is listed by the State of Nebraska to protect the beneficial use of public drinking water. Where the natural background level is greater than the criterion, the State of Nebraska states that the background level is to be used in place of the criterion. The elevated total dissolved solids levels are believed indicative of natural background conditions.

Note: Some of Nebraska's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

(D) Immunoassay analysis.

(E) The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, cycloate, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, isopropalin, metolachlor, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, phorate, profluralin, prometon, propachlor, propazine, simazine, terbufos, triallate, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

Plate 378. Summary of water quality conditions monitored in the Missouri River at Omaha, Nebraska (i.e., site MORRR0619) during the 5-year period 2004 through 2008.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit(A)	No. of Obs.	Mean(B)	Median	Min.	Max.	State WQS Criteria(C)	No. of WQS Exceedences	Percent WQS Exceedence
Streamflow (cfs)	1	84	27,398	28,000	13,300	58,400	-----	-----	-----
Water Temperature (C)	0.1	84	15.6	17.4	0.0	28.1	32(1,5)	0	0%
Dissolved Oxygen (mg/l)	0.1	83	9.4	8.7	6.1	15.0	5(1,6)	0	0%
Dissolved Oxygen (% Sat.)	0.1	83	94.3	95.4	75.3	120.7	-----	-----	-----
Specific Conductance (umho/cm)	1	84	707	702	470	899	2,000(3)	0	0%
pH (S.U.)	0.1	82	8.2	8.3	6.9	8.9	6.5(1,6), 9.0(1,5)	0	0%
Oxidation-Reduction Potential	1	30	403	401	315	543	-----	-----	-----
Alkalinity, Total (mg/l)	7	82	190	190	140	250	-----	0	0%
Ammonia, Total (mg/l)	0.02	82	-----	0.06	n.d.	0.79	4.7 (1,5,8), 1.3 (1,7,8)	0	0%
Carbon, Total Organic (mg/l)	0.05	80	4.3	3.7	2.3	17.2	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	82	19	14	n.d.	93	-----	-----	-----
Chloride (mg/l)	1	81	16	15	7	84	250(2), 860(9), 230(10)	0	0%
Dissolved Solids, Total (mg/l)	5	46	510	510	328	640	500(2)	31(12)	67%(12)
Hardness, Total (mg/l)	0.4	17	282	271	231	379	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	82	1.1	0.8	n.d.	5.1	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	81	1.77	1.50	n.d.	5.4	10(2,5), 100(3,5)	0	0%
Phosphorus, Total (mg/l)	0.02	81	0.28	0 17	0.05	2.40	-----	-----	-----
Suspended Solids, Total (mg/l)	4	82	162	68	13	1,772	-----	-----	-----
Turbidity (NTU)	1	83	121	57	4	1,324	-----	-----	-----
Aluminum, Dissolved (mg/l)	25	6	-----	n.d.	n.d.	60	750(9), 87(10), 200(2)	0	0%
Antimony, Dissolved (ug/l)	0.5	7	-----	n.d.	n.d.	2.0	88(9), 30(10), 6(2)	0	0%
Arsenic, Dissolved (ug/l)	1	19	-----	n.d.	n.d.	5	340(9), 16.7(10,11), 10(2)	0	0%
Barium, Dissolved (ug/l)	5	7	78	74	66	106	2,000(2)	0	0%
Beryllium, Dissolved (ug/l)	2	8	-----	n.d.	n.d.	n.d.	130(5), 5.3(10), 4(2)	0	0%
Cadmium, Dissolved (ug/l)	0.5	19	-----	n.d.	n.d.	n.d.	16(9), 0.49(10), 5(2)	0	0%
Chromium, Dissolved (ug/l)	10	19	-----	n.d.	n.d.	n.d.	1,340(9), 174(10), 100(2)	0	0%
Copper, Dissolved (ug/l)	2	19	-----	n.d.	n.d.	n.d.	34(9), 21(10), 1,000(2)	0	0%
Lead, Dissolved (ug/l)	2	19	-----	n.d.	n.d.	n.d.	188(9), 7.3(10)	0	0%
Mercury, Dissolved (ug/l)	0.02	18	-----	n.d.	n.d.	n.d.	1.4(9)	0	0%
Mercury, Total (ug/l)	0.02	18	-----	n.d.	n.d.	0.02	0.77(10), 2(2)	0	0%
Nickel, Dissolved (ug/l)	10	19	-----	n.d.	n.d.	n.d.	1,088(9), 121(10)	0	0%
Selenium, Total (ug/l)	4	19	-----	n.d.	n.d.	4	20(3,9), 5(10), 50(2)	0	0%
Silver, Dissolved (ug/l)	1	18	-----	n.d.	n.d.	n.d.	19(9), 100(2)	0	0%
Thallium, Dissolved (ug/l)	0.5	7	-----	n.d.	n.d.	n.d.	1,400(5), 6.3(10,11), 2(2)	0	0%
Zinc, Dissolved (ug/l)	10	19	-----	n.d.	n.d.	39	273(9,10), 5,000(2)	0	0%
Acetochlor, Total (ug/l)(D)	0.05	9	-----	n.d.	n.d.	2.20	-----	-----	-----
Alachlor, Total (ug/l)(D)	0.05	60	-----	n.d.	n.d.	0.34	760(9), 76(10), 2(2)	0	0%
Atrazine, Total (ug/l)(D)	0.05	69	-----	n.d.	n.d.	2.10	330(9), 12(10), 3(2)	0	0%
Metolachlor, Total (ug/l)(D)	0.05	69	-----	n.d.	n.d.	1.60	390(9), 100(10)	0	0%
Pesticide Scan (ug/l)(E)	0.05						-----	-----	-----
Acetochlor, Total (ug/l)		13	-----	n.d.	n.d.	0.46	-----	-----	-----
Atrazine, Total (ug/l)		13	-----	n.d.	n.d.	1.00	330(9), 12(10), 3(2)	0	0%
Metolachlor, Total (ug/l)		13	-----	n.d.	n.d.	0.40	390(9), 100(10)	0	0%

n.d. = Not detected.

(A) Detection limits given for the parameters Stream Flow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

(1) Criteria for the protection of Class I Warmwater Aquatic Life (Nebraska).
(2) Criteria for the protection of domestic water supply waters.
(3) Criteria for the protection of agricultural water supply waters.
(4) Criteria for the protection of commerce and industry waters.
(5) Daily maximum criterion (monitoring results directly comparable to criterion).
(6) Daily minimum criterion (monitoring results directly comparable to criterion).
(7) 30-day average criterion (monitoring results not directly comparable to criterion).
(8) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
(9) Acute (CMC) criterion for the protection of freshwater aquatic life.
(10) Chronic (CCC) criterion for the protection of freshwater aquatic life.
(11) Criterion for the protection of human health.
(12) Criterion for total dissolved solids is listed by the State of Nebraska to protect the beneficial use of public drinking water. Where the natural background level is greater than the criterion, the State of Nebraska states that the background level is to be used in place of the criterion. The elevated total dissolved solids levels are believed indicative of natural background conditions.

Note: Some of Nebraska's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

(D) Immunoassay analysis.

(E) The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, cycloate, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, isopropalin, metolachlor, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, phorate, profluralin, prometon, propachlor, propazine, simazine, terbufos, triallate, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

Plate 379. Summary of water quality conditions monitored in the Missouri River at Nebraska City, Nebraska (i.e., site MORRR0563) during the 5-year period 2004 through 2008.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit[A]	No. of Obs.	Mean[B]	Median	Min.	Max.	State WQS Criteria[C]	No. of WQS Exceedences	Percent WQS Exceedence
Streamflow (cfs)	1	85	34,280	32,900	16,700	117,000	-----	-----	-----
Water Temperature (C)	0.1	85	15.9	17.0	0.0	28.5	32[1,5]	0	0%
Dissolved Oxygen (mg/l)	0.1	84	9.1	8.5	5.4	14.7	5[1,6]	0	0%
Dissolved Oxygen (% Sat.)	0.1	84	91.4	92.9	68.5	104.8	-----	-----	-----
Specific Conductance (umho/cm)	1	85	682	689	472	822	2,000[3]	0	0%
pH (S.U.)	0.1	84	8.2	8.3	7.4	8.8	6.5[1,6], 9.0[1,5]	0	0%
Oxidation-Reduction Potential	1	28	399	397	312	535	-----	-----	-----
Alkalinity, Total (mg/l)	7	83	187	190	130	242	-----	0	0%
Ammonia, Total (mg/l)	0.02	83	-----	0.11	n.d.	0.82	4.7 [1,5,8], 1.3 [1,7,8]	0	0%
Carbon, Total Organic (mg/l)	0.05	81	4.4	3.7	2.0	17.8	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	83	23	16	n.d.	137	-----	-----	-----
Chloride (mg/l)	1	83	24	23	8	48	250[2], 860[9], 230[10]	0	0%
Dissolved Solids, Total (mg/l)	5	46	479	490	318	610	500[2]	20[12]	43%[12]
Hardness, Total (mg/l)	0.4	19	266	262	226	311	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	83	1.4	1.1	0.4	5.4	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	82	1.69	1.70	0.04	4.00	10[2,5], 100[3,5]	0	0%
Phosphorus, Total (mg/l)	0.02	82	0.42	0 30	0.09	2.60	-----	-----	-----
Suspended Solids, Total (mg/l)	4	83	226	97	4	1,888	-----	-----	-----
Turbidity (NTU)	1	82	150	71	5	880	-----	-----	-----
Aluminum, Dissolved (mg/l)	25	6	-----	n.d.	n.d.	50	750[9], 87[10], 200[2]	0	0%
Antimony, Dissolved (ug/l)	0.5	7	-----	n.d.	n.d.	0.5	88[9], 30[10], 6[2]	0	0%
Arsenic, Dissolved (ug/l)	1	19	-----	n.d.	n.d.	5	340[9], 16.7[10,11], 10[2]	0	0%
Barium, Dissolved (ug/l)	5	7	108	106	79	135	2,000[2]	0	0%
Beryllium, Dissolved (ug/l)	2	8	-----	n.d.	n.d.	n.d.	130[5], 5.3[10], 4[2]	0	0%
Cadmium, Dissolved (ug/l)	0.5	19	-----	n.d.	n.d.	n.d.	15[9], 0.48[10], 5[2]	0	0%
Chromium, Dissolved (ug/l)	10	19	-----	n.d.	n.d.	n.d.	1,303[9], 170[10], 100[2]	0	0%
Copper, Dissolved (ug/l)	2	18	-----	n.d.	n.d.	n.d.	33[9], 20[10], 1,000[2]	0	0%
Lead, Dissolved (ug/l)	2	19	-----	n.d.	n.d.	n.d.	181[9], 7.1[10]	0	0%
Mercury, Dissolved (ug/l)	0.02	18	-----	n.d.	n.d.	n.d.	1.4[9]	0	0%
Mercury, Total (ug/l)	0.02	18	-----	n.d.	n.d.	0.03	0.77[10], 2[2]	0	0%
Nickel, Dissolved (ug/l)	10	19	-----	n.d.	n.d.	n.d.	1,058[9], 117[10]	0	0%
Selenium, Total (ug/l)	4	19	-----	n.d.	n.d.	5	20[3,9], 5[10], 50[2]	0	0%
Silver, Dissolved (ug/l)	1	19	-----	n.d.	n.d.	n.d.	14[9], 100[2]	0	0%
Thallium, Dissolved (ug/l)	0.5	7	-----	n.d.	n.d.	n.d.	1,400[5], 6.3[10,11], 2[2]	0	0%
Zinc, Dissolved (ug/l)	10	19	-----	n.d.	n.d.	72	265[9,10], 5,000[2]	0	0%
Acetochlor, Total (ug/l)[D]	0.05	9	-----	n.d.	n.d.	2.50	-----	-----	-----
Alachlor, Total (ug/l)[D]	0.05	60	-----	n.d.	n.d.	0.30	760[9], 76[10], 2[2]	0	0%
Atrazine, Total (ug/l)[D]	0.05	70	-----	n.d.	n.d.	4.64	330[9], 12[10], 3[2]	0, 0, 3	0%, 0%, 4%
Metolachlor, Total (ug/l)[D]	0.05	70	-----	n.d.	n.d.	2.40	390[9], 100[10]	0	0%
Pesticide Scan (ug/l)[E]	0.05						-----	-----	-----
Acetochlor, Total (ug/l)		13	-----	n.d.	n.d.	0.54	-----	-----	-----
Alachlor, Total (ug/l)		13	n.d.	n.d.	n.d.	0.10	760[9], 76[10], 2[2]	0	0%
Atrazine, Total (ug/l)		13	-----	n.d.	n.d.	6.60	330[9], 12[10], 3[2]	0, 0, 1	0%, 0%, 8%
Metolachlor, Total (ug/l)		13	-----	n.d.	n.d.	2.80	390[9], 100[10]	0	0%

n.d. = Not detected.

[A] Detection limits given for the parameters Stream Flow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

[B] Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

[C] Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

(1) Criteria for the protection of Class I Warmwater Aquatic Life (Nebraska).
(2) Criteria for the protection of domestic water supply waters.
(3) Criteria for the protection of agricultural water supply waters.
(4) Criteria for the protection of commerce and industry waters.
(5) Daily maximum criterion (monitoring results directly comparable to criterion).
(6) Daily minimum criterion (monitoring results directly comparable to criterion).
(7) 30-day average criterion (monitoring results not directly comparable to criterion).
(8) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
(9) Acute (CMC) criterion for the protection of freshwater aquatic life.
(10) Chronic (CCC) criterion for the protection of freshwater aquatic life.
(11) Criterion for the protection of human health.
(12) Criterion for total dissolved solids is listed by the State of Nebraska to protect the beneficial use of public drinking water. Where the natural background level is greater than the criterion, the State of Nebraska states that the background level is to be used in place of the criterion. The elevated total dissolved solids levels are believed indicative of natural background conditions.

Note: Some of Nebraska's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

[D] Immunoassay analysis.

[E] The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, cycloate, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, isopropalin, metolachlor, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, phorate, profluralin, prometon, propachlor, propazine, simazine, terbufos, triallate, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

Plate 380. Summary of water quality conditions monitored in the Missouri River at Rulo, Nebraska (i.e., site MORRR0498) during the 5-year period 2004 through 2008.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit[A]	No. of Obs.	Mean[B]	Median	Min.	Max.	State WQS Criteria[C]	No. of WQS Exceedences	Percent WQS Exceedence
Streamflow (cfs)	1	84	36,018	33,400	17,500	131,000	-----	-----	-----
Water Temperature (C)	0.1	84	16.7	18.0	0.0	30.6	32[1,5]	0	0%
Dissolved Oxygen (mg/l)	0.1	82	9.0	8.4	5.0	14.6	5[1,6]	0	0%
Dissolved Oxygen (% Sat.)	0.1	82	91.8	92.5	65.6	111.8	-----	-----	-----
Specific Conductance (umho/cm)	1	84	683	687	473	796	2,000[3]	0	0%
pH (S.U.)	0.1	83	8.2	8.2	7.5	8.7	6.5[1,6], 9.0[1,5]	0	0%
Oxidation-Reduction Potential	1	30	395	385	303	538	-----	-----	-----
Alkalinity, Total (mg/l)	7	82	186	190	120	242	-----	0	0%
Ammonia, Total (mg/l)	0.02	82	-----	0.06	n.d.	0.83	5.7 [1,5,8], 1.4 [1,7,8]	0	0%
Carbon, Total Organic (mg/l)	0.05	80	4.1	3.5	1.4	13.5	-----	-----	-----
Chemical Oxygen Demand (mg/l)	2	82	20	15	n.d.	114	-----	-----	-----
Chloride (mg/l)	1	81	21	21	7	35	250[2], 860[9], 230[10]	0	0%
Dissolved Solids, Total (mg/l)	5	45	483	486	320	640	500[2]	17[12]	38%[12]
Hardness, Total (mg/l)	0.4	19	264	259	226	331	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	82	1.4	1.1	0.5	5.4	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	1	1.90	1.80	0.03	4.30	10[2,5], 100[3,5]	0	0%
Phosphorus, Total (mg/l)	0.02	81	0.41	0 30	0 10	2.80	-----	-----	-----
Suspended Solids, Total (mg/l)	4	82	223	111	14	2,164	-----	-----	-----
Turbidity (NTU)	1	82	174	76	4	2,125	-----	-----	-----
Aluminum, Dissolved (mg/l)	25	5	-----	n.d.	n.d.	60	750[9], 87[10], 200[2]	0	0%
Antimony, Dissolved (ug/l)	0.5	7	-----	n.d.	n.d.	1.2	88[9], 30[10], 6[2]	0	0%
Arsenic, Dissolved (ug/l)	1	19	-----	n.d.	n.d.	5	340[9], 16.7[10,11], 10[2]	0	0%
Barium, Dissolved (ug/l)	5	7	108	107	76	136	2,000[2]	0	0%
Beryllium, Dissolved (ug/l)	2	8	-----	n.d.	n.d.	n.d.	130[5], 5.3[10], 4[2]	0	0%
Cadmium, Dissolved (ug/l)	0.5	19	-----	n.d.	n.d.	n.d.	15[9], 0.48[10], 5[2]	0	0%
Chromium, Dissolved (ug/l)	10	19	-----	n.d.	n.d.	20	1,291[9], 168[10], 100[2]	0	0%
Copper, Dissolved (ug/l)	2	19	-----	n.d.	n.d.	30	33[9], 20[10], 1,000[2]	0, 1, 0	0%, 5%, 0%
Lead, Dissolved (ug/l)	2	19	-----	n.d.	n.d.	n.d.	179[9], 7.0[10]	0	0%
Mercury, Dissolved (ug/l)	0.02	18	-----	n.d.	n.d.	n.d.	1.4[9]	0	0%
Mercury, Total (ug/l)	0.02	17	-----	n.d.	n.d.	0.02	0.77[10], 2[2]	0	0%
Nickel, Dissolved (ug/l)	10	19	-----	n.d.	n.d.	70	1,047[9], 116[10]	0	0%
Selenium, Total (ug/l)	4	19	-----	n.d.	n.d.	6	20[3,9], 5[10], 50[2]	0, 1, 0	0%, 5%, 0%
Silver, Dissolved (ug/l)	1	19	-----	n.d.	n.d.	n.d.	18[9], 100[2]	0	0%
Thallium, Dissolved (ug/l)	0.5	7	-----	n.d.	n.d.	n.d.	1,400[5], 6.3[10,11], 2[2]	0	0%
Zinc, Dissolved (ug/l)	10	19	-----	n.d.	n.d.	41	262[9,10], 5,000[2]	0	0%
Acetochlor, Total (ug/l)[D]	0.05	9	-----	n.d.	0 10	0.70	-----	-----	-----
Alachlor, Total (ug/l)[D]	0.05	60	-----	n.d.	n.d.	0.23	760[9], 76[10], 2[2]	0	0%
Atrazine, Total (ug/l)[D]	0.05	69	-----	n.d.	0 10	5.10	330[9], 12[10], 3[2]	0, 0, 3	0%, 0%, 4%
Metolachlor, Total (ug/l)[D]	0.05	69	-----	n.d.	n.d.	2.01	390[9], 100[10]	0	0%
Pesticide Scan (ug/l)[E]	0.05						-----	-----	-----
Acetochlor, Total (ug/l)		13	-----	n.d.	n.d.	0.70	-----	-----	-----
Atrazine, Total (ug/l)		13	-----	n.d.	n.d.	6.00	330[9], 12[10], 3[2]	0, 0, 2	0%, 0%, 15%
Metolachlor, Total (ug/l)		13	-----	n.d.	n.d.	2.20	390[9], 100[10]	0	0%

n.d. = Not detected.

(A) Detection limits given for the parameters Stream Flow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

(B) Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

(C) Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

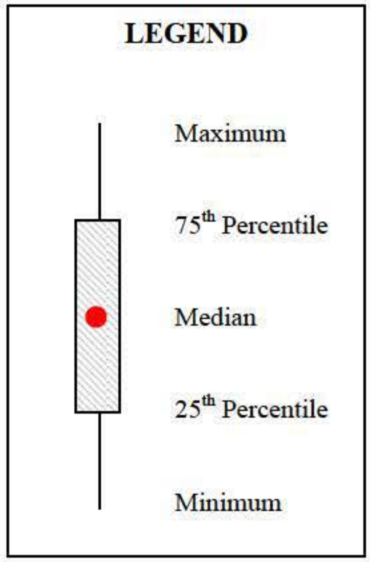
- (1) Criteria for the protection of Class I Warmwater Aquatic Life (Nebraska).
- (2) Criteria for the protection of domestic water supply waters.
- (3) Criteria for the protection of agricultural water supply waters.
- (4) Criteria for the protection of commerce and industry waters.
- (5) Daily maximum criterion (monitoring results directly comparable to criterion).
- (6) Daily minimum criterion (monitoring results directly comparable to criterion).
- (7) 30-day average criterion (monitoring results not directly comparable to criterion).
- (8) Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- (9) Acute (CMC) criterion for the protection of freshwater aquatic life.
- (10) Chronic (CCC) criterion for the protection of freshwater aquatic life.
- (11) Criterion for the protection of human health.
- (12) Criterion for total dissolved solids is listed by the State of Nebraska to protect the beneficial use of public drinking water. Where the natural background level is greater than the criterion, the State of Nebraska states that the background level is to be used in place of the criterion. The elevated total dissolved solids levels are believed indicative of natural background conditions.

Note: Some of Nebraska's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

(D) Immunoassay analysis.

(E) The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, cycloate, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, isopropalin, metolachlor, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, phorate, profluralin, prometon, propachlor, propazine, simazine, terbufos, triallate, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

Plate 381. Distribution plots (i.e., box plots) for selected parameters monitored at locations along the Missouri River from Gavins Point Dam to Rulo, Nebraska during the 5-year period of 2004 through 2008.



Note: Monitoring location refers to the River Mile (RM) along the Missouri River where the monitoring site was located.

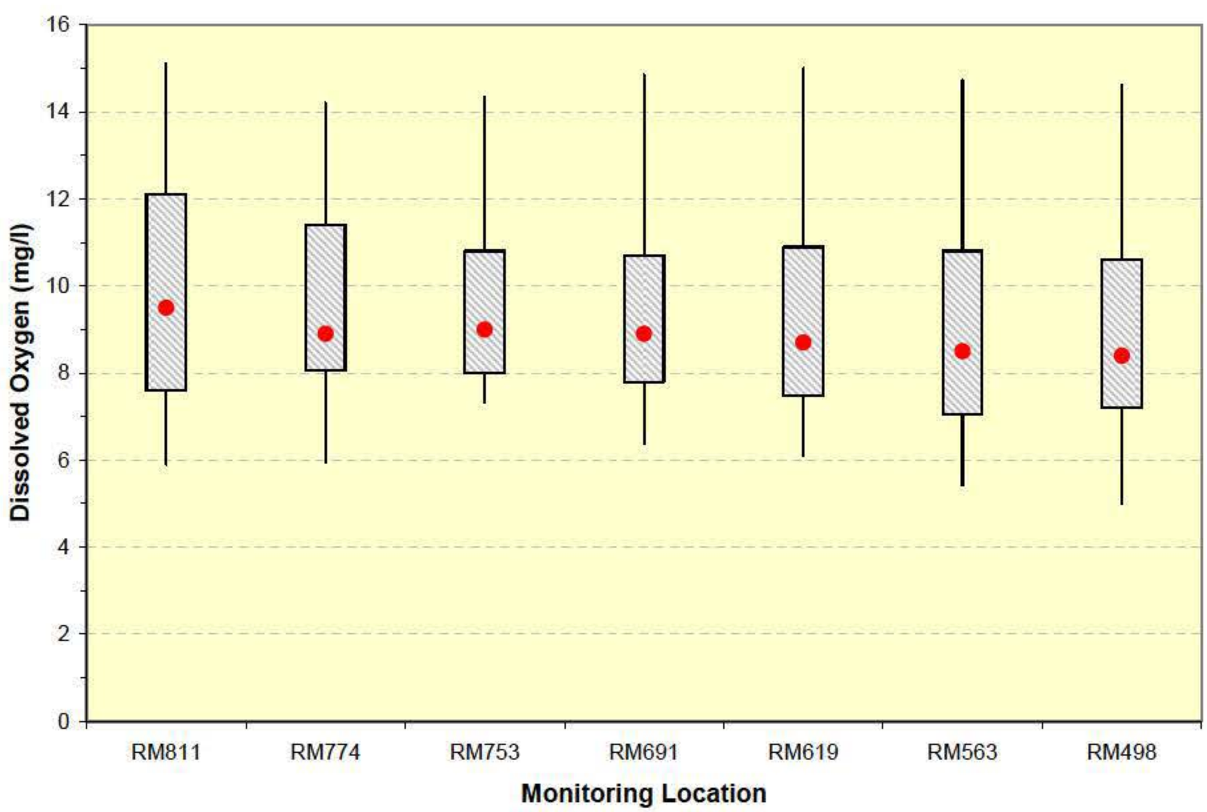
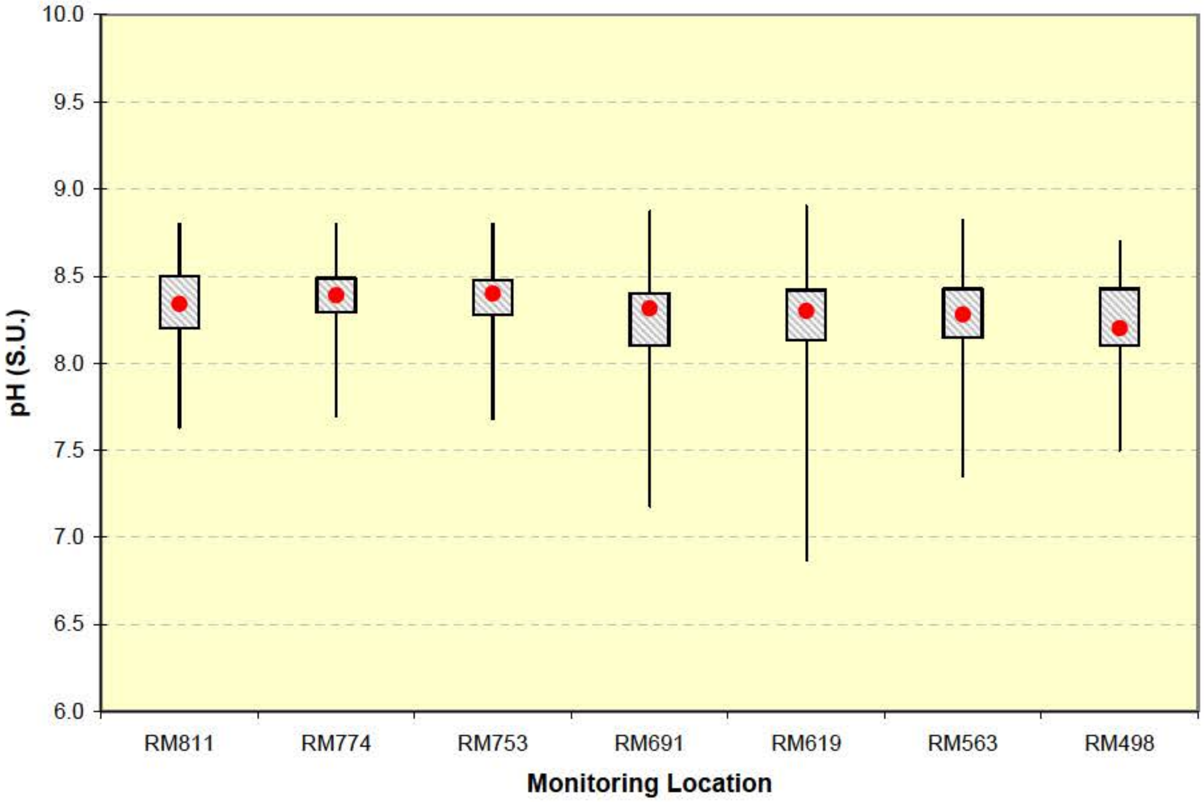


Plate 381. (Continued).



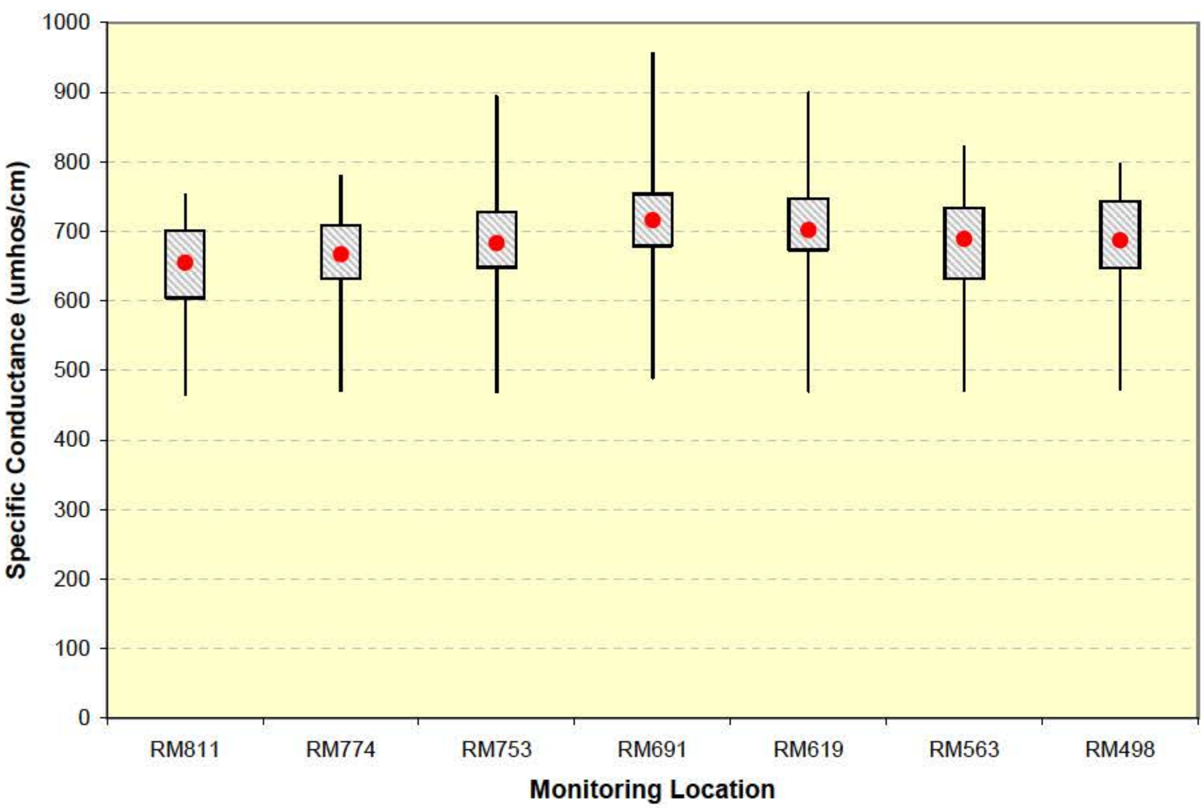
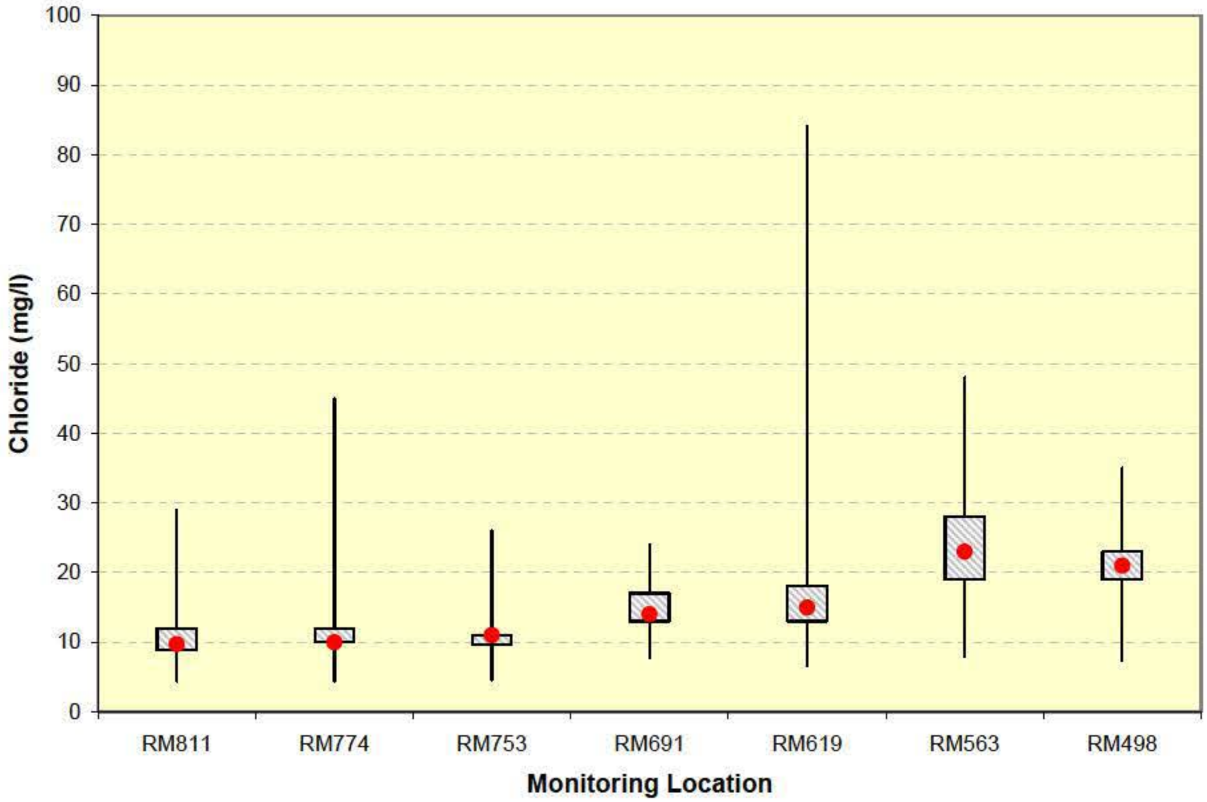


Plate 381. (Continued).



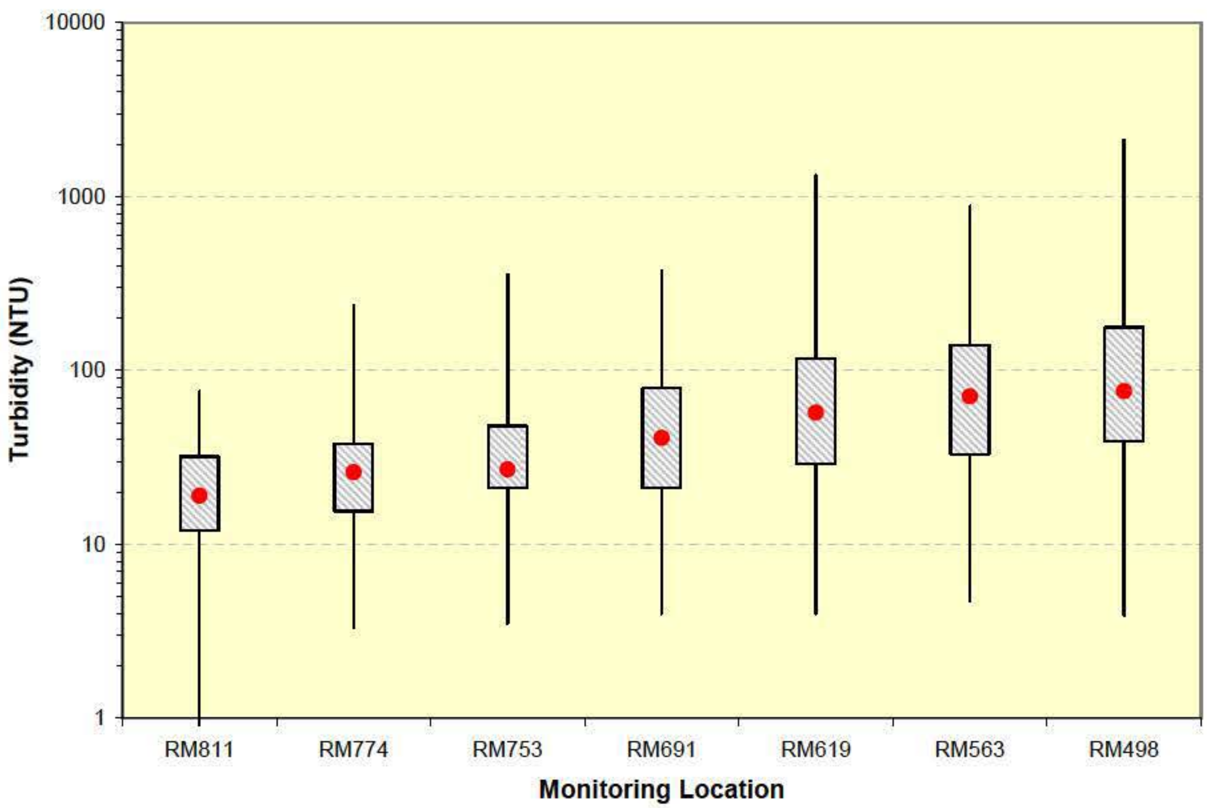
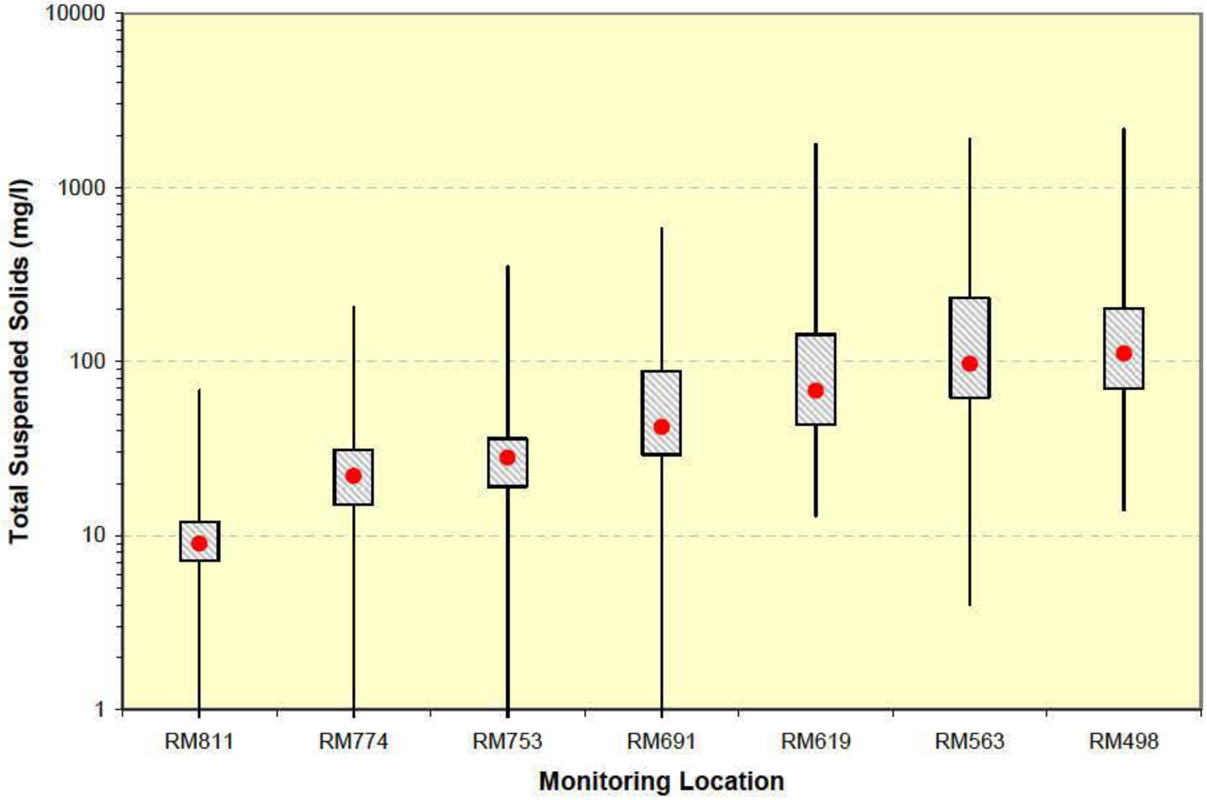


Plate 381. (Continued).



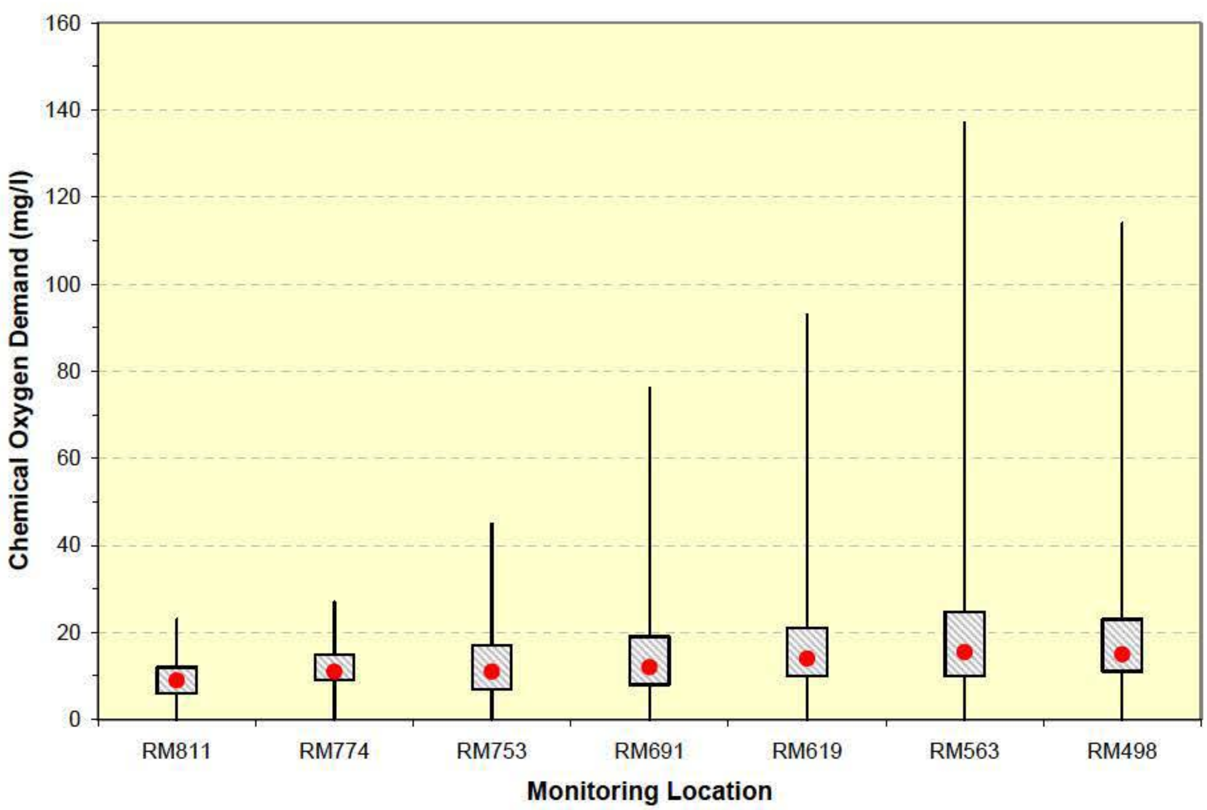
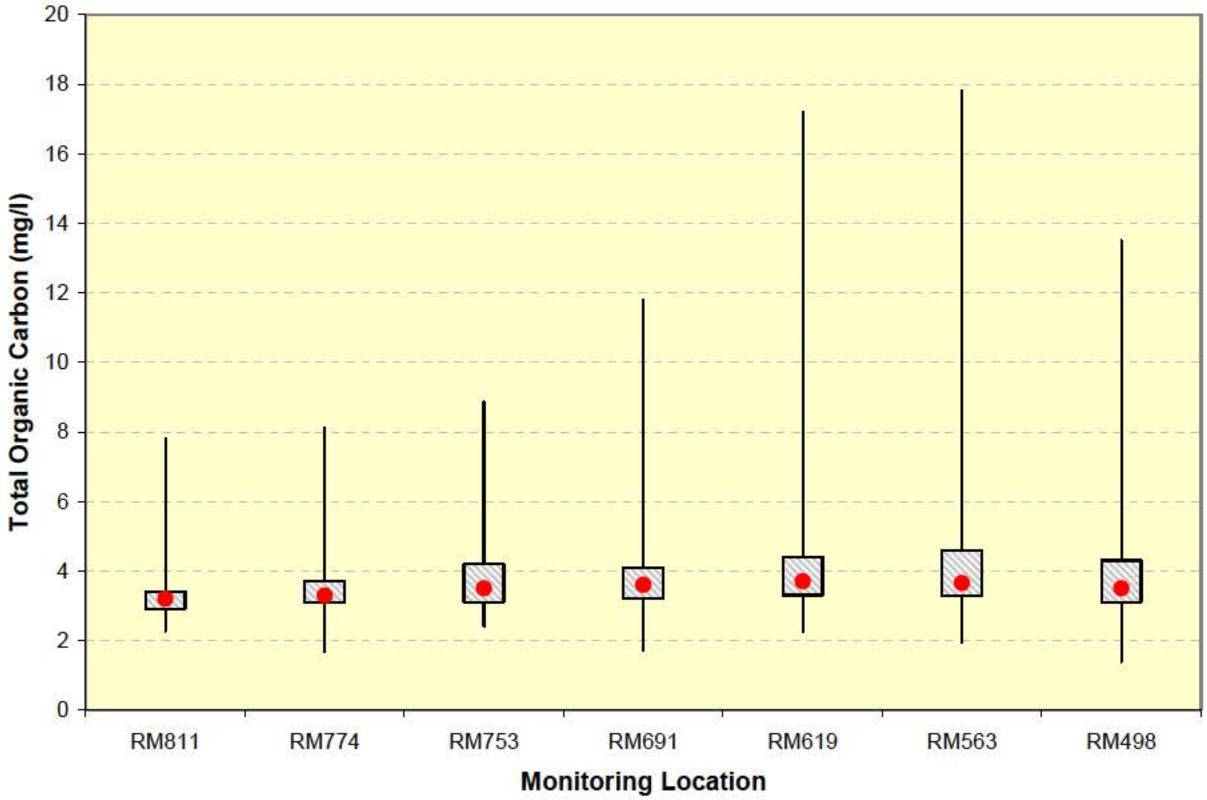


Plate 381. (Continued).



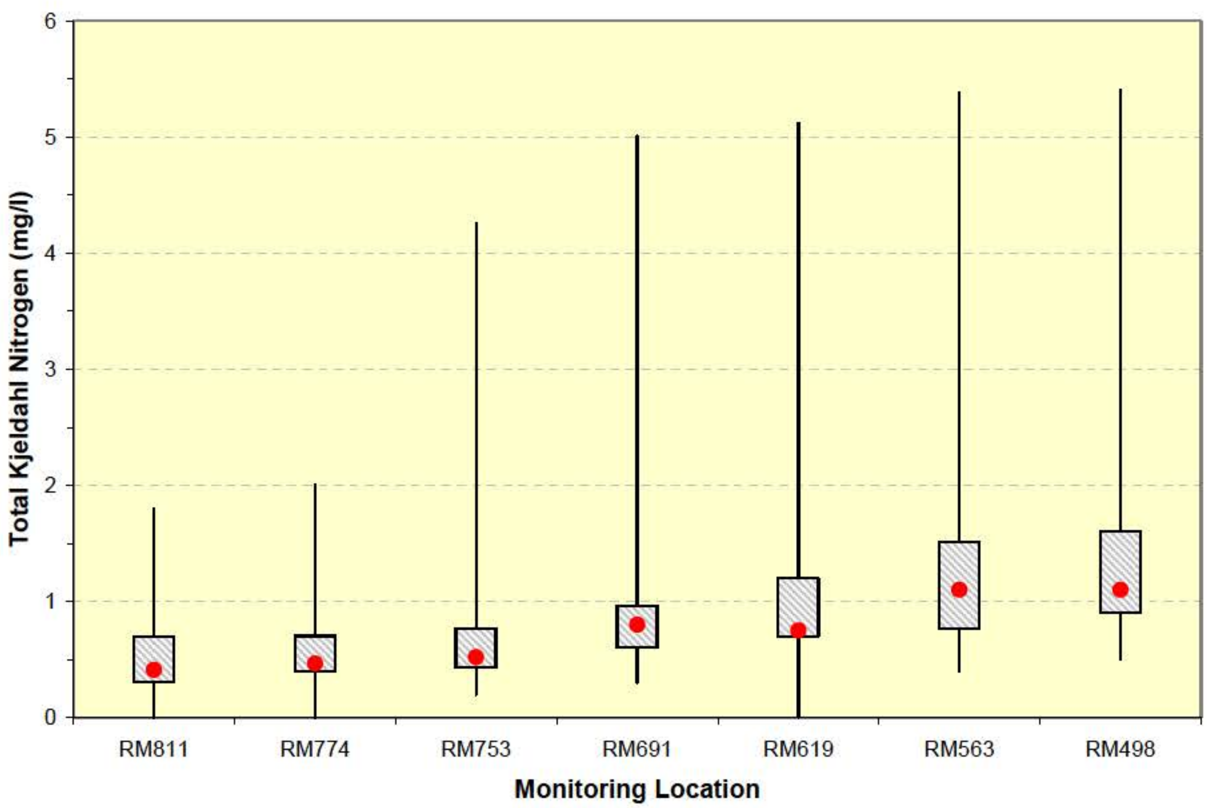
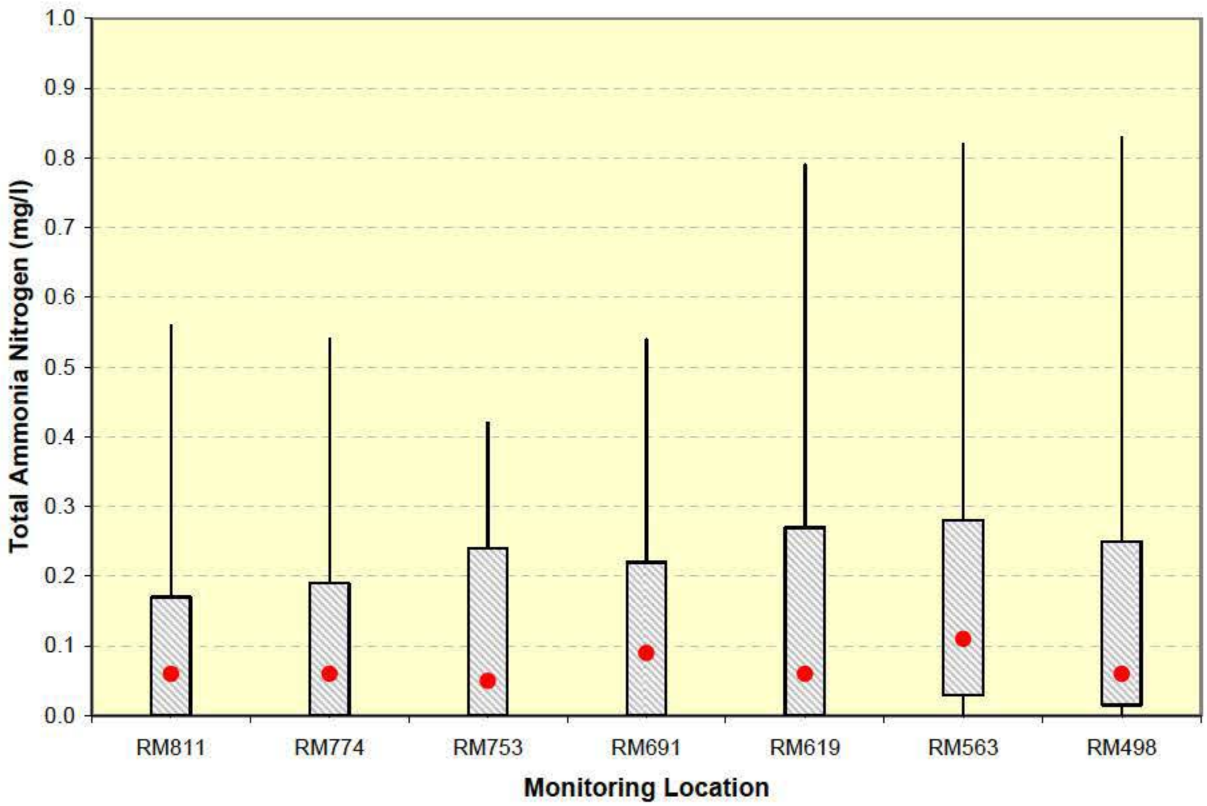


Plate 381. (Continued).



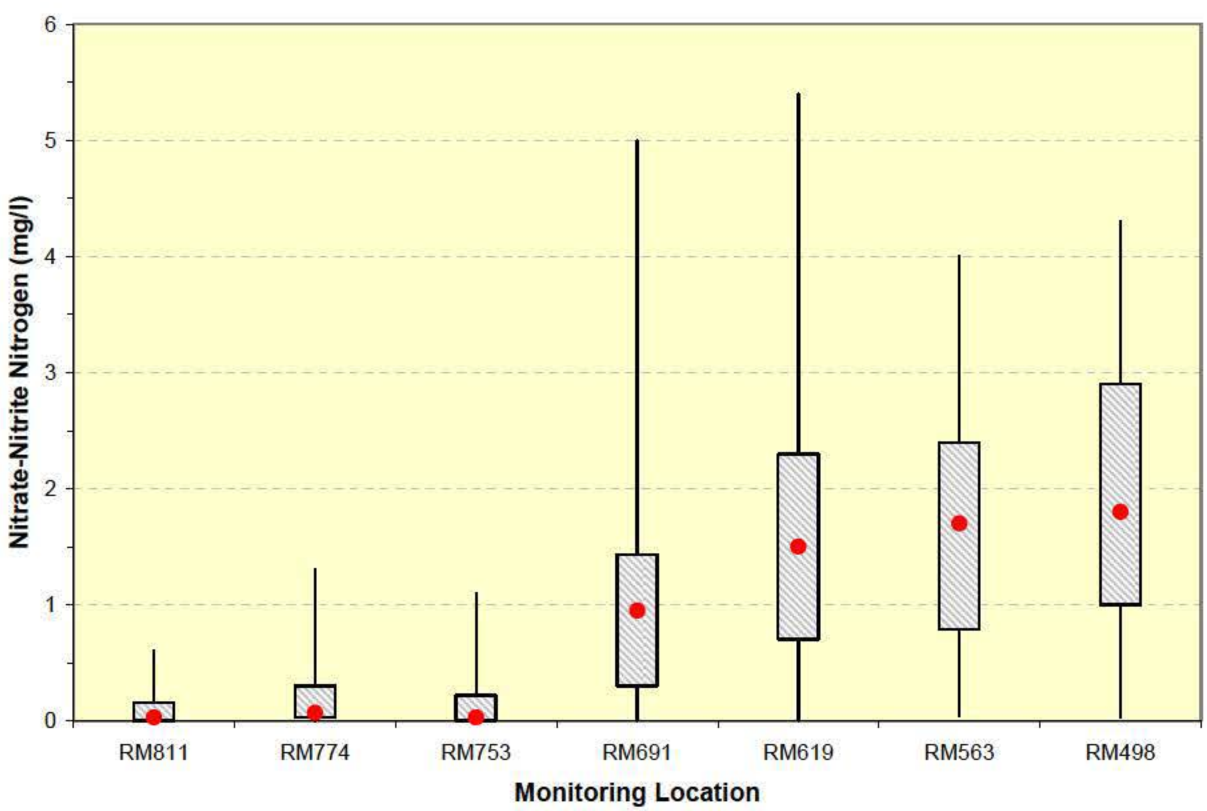
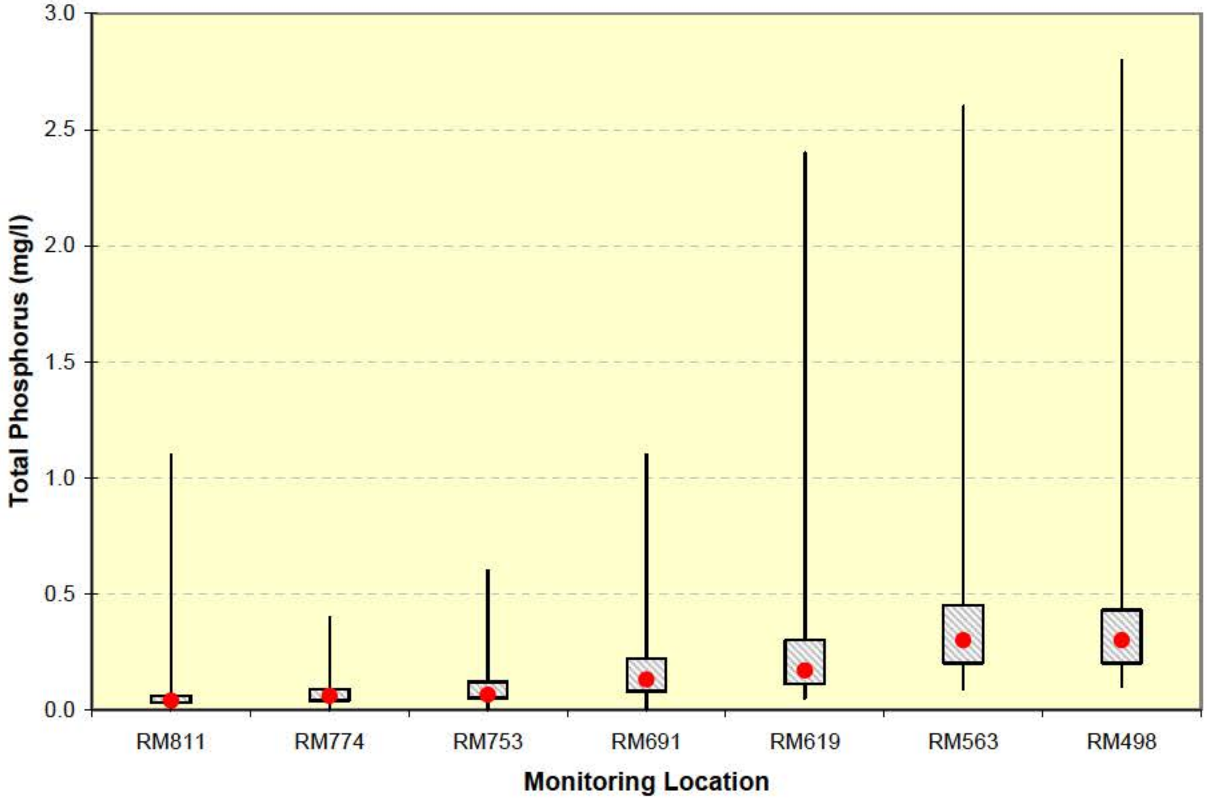


Plate 381. (Continued).



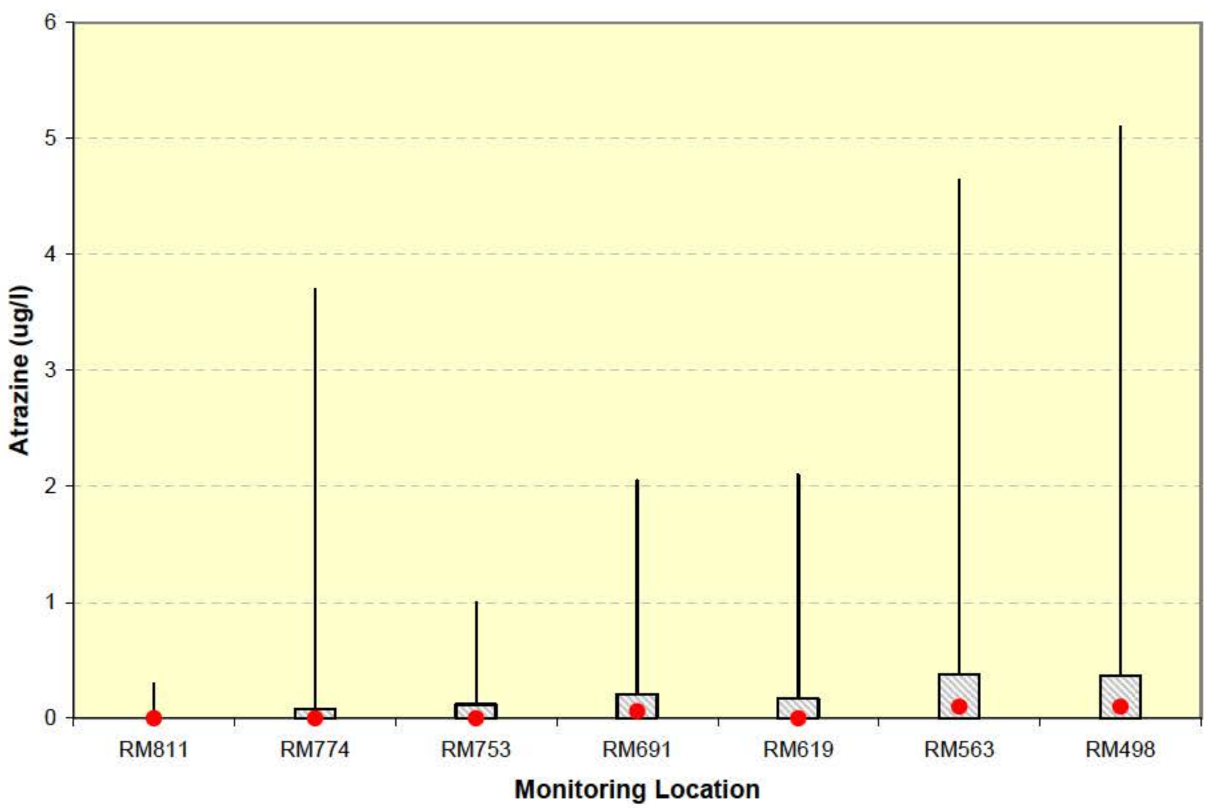


Plate 381. (Continued).

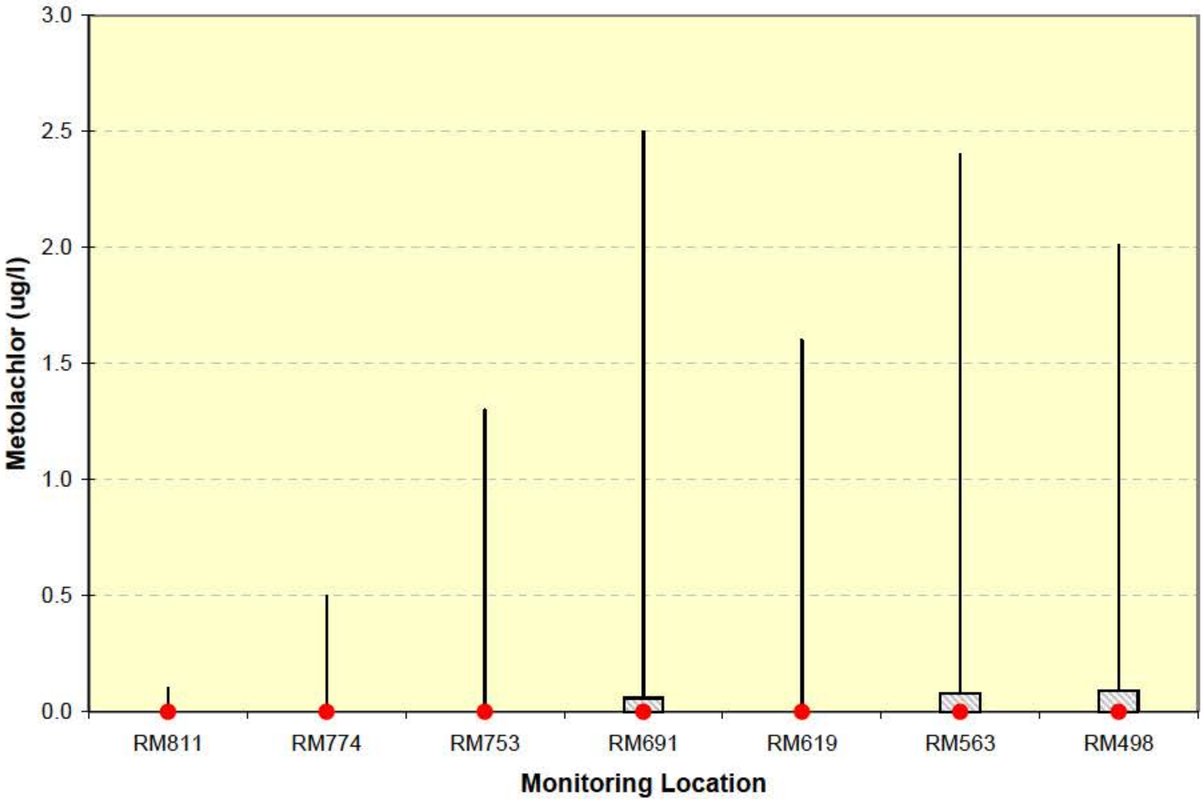


Plate 382. Summary of monthly (May through September) water quality conditions monitored in Lake Audubon (i.e., site AUDLKND1) during 2002 and 2006.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit[A]	No. of Obs.	Mean[B]	Median	Min.	Max.	State WQS Criteria[C]	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation	1	4	1846.9	1847.0	1846.8	1847.0	-----	-----	-----
Water Temperature (C)	0.1	91	18.3	18.3	10.4	15.5	29.4[1,2]	0	0%
Dissolved Oxygen (mg/l)	0.1	91	8.1	8.3	1.7	9.8	5.0[1,3]	4	4%
Dissolved Oxygen (% Sat.)	0.1	91	89.8	94.3	19.1	103.2	-----	-----	-----
Specific Conductance (umho/cm)	1	91	891	911	228	969	-----	-----	-----
pH (S.U.)	0.1	91	8.5	8.5	7.8	8.8	6.5[1,3], 9.0[1,2]	0	0%
Oxidation-Reduction Potential (mV)	1	67	379	325	315	477	-----	-----	-----
Secchi Depth (in)	1	7	88	67	48	130	-----	-----	-----
Alkalinity, Total (mg/l)	7	12	210	121	170	223	-----	-----	-----
Ammonia, Total (mg/l)	0.01	8	-----	0.02	n.d.	0.08	2.14 [1,2,4], 0.79 [1,4,5]	0	0%
Carbon, Total Organic (mg/l)	0.05	12	5.0	5.0	4.6	5.8	-----	-----	-----
Chlorophyll *a* (ug/l) - Lab Determined	1	4	-----	1.5	n.d.	3	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	8	631	635	590	670	-----	-----	-----
Hardness, Total (mg/l)	0.4	6	265	272	245	276	-----	-----	-----
Iron, Dissolved (ug/l)	40	8	-----	n.d.	n.d.	40	-----	-----	-----
Iron, Total (ug/l)	40	8	209	208	80	383	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	12	-----	0.2	n.d.	0.7	-----	-----	-----
Manganese, Dissolved (ug/l)	2	8	2 5	2.5	1	4	-----	-----	-----
Manganese, Total (ug/l)	2	8	13	11	4	24	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	12	-----	n.d.	n.d.	0.10	-----	-----	-----
Phosphorus, Dissolved (mg/l)	0.01	8	-----	n.d.	n.d.	0.01	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	12	0.07	0.03	n.d.	0.35	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.01	12	-----	n.d.	n.d.	n.d.	-----	-----	-----
Sulfate (mg/l)	1	8	321	320	310	330	-----	-----	-----
Suspended Solids, Total (mg/l)	4	12	-----	n.d.	n.d.	8	-----	-----	-----
Antimony, Dissolved (ug/l)	0.5	2	-----	n.d.	n.d.	n.d.	5.6[8]	0	0%
Arsenic, Dissolved (ug/l)	1	2	-----	n.d.	n.d.	3.	340[6], 150[7], 10[8]	0	0%
Beryllium, Dissolved (ug/l)	2	2	-----	n.d.	n.d.	n.d.	4[8]	0	0%
Cadmium, Dissolved (ug/l)	0.2	2	-----	n.d.	n.d.	n.d.	14.0[6], 5.4[7], 5[8]	0	0%
Chromium, Dissolved (ug/l)	10	2	-----	n.d.	n.d.	n.d.	4,092[6], 196[7], 100[8]	0	0%
Copper, Dissolved (ug/l)	2	2	-----	n.d.	n.d.	n.d.	35.9[6], 21.9[7], 1,000[8]	0	0%
Lead, Dissolved (ug/l)	0.5	2	-----	n.d.	n.d.	n.d.	292[6], 11.4[7], 15[8]	0	0%
Nickel, Dissolved (ug/l)	10	2	-----	n.d.	n.d.	n.d.	1,094[6], 121[7], 100[8]	0	0%
Selenium, Total (ug/l)	1	2	-----	n.d.	n.d.	n.d.	20[6], 5[7], 50[8]	0	0%
Silver, Dissolved (ug/l)	1	2	-----	n.d.	n.d.	n.d.	14.7[6]	0	0%
Zinc, Dissolved (ug/l)	10	2	-----	n.d.	n.d.	n.d.	280[6,7], 7,400[8]	0	0%
Pesticide Scan (ug/l)[D]	0.05	1	-----	n.d.	n.d.	n.d.	-----	-----	-----
Microcystin	0.2	4	-----	n.d.	n.d.	n.d.	-----	-----	-----

n.d. = Not detected.

[A] Detection limits given for the parameters Stream Flow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

[B] Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d., mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

[C] Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- [1] Criteria for Class 2 lakes.
- [2] Daily maximum criterion (monitoring results directly comparable to criterion).
- [3] Daily minimum criterion (monitoring results directly comparable to criterion).
- [4] Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- [5] 30-day average criterion (monitoring results not directly comparable to criterion).
- [6] Acute criterion for aquatic life.
- [7] Chronic criterion for aquatic life.
- [8] Human health criterion for surface waters.

Note: Some of North Dakota's criteria for metals (i.e , cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

[D] The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, cycloate, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, isopropalin, metolachlor, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, phorate, profluralin, prometon, propachlor, propazine, simazine, terbufos, triallate, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

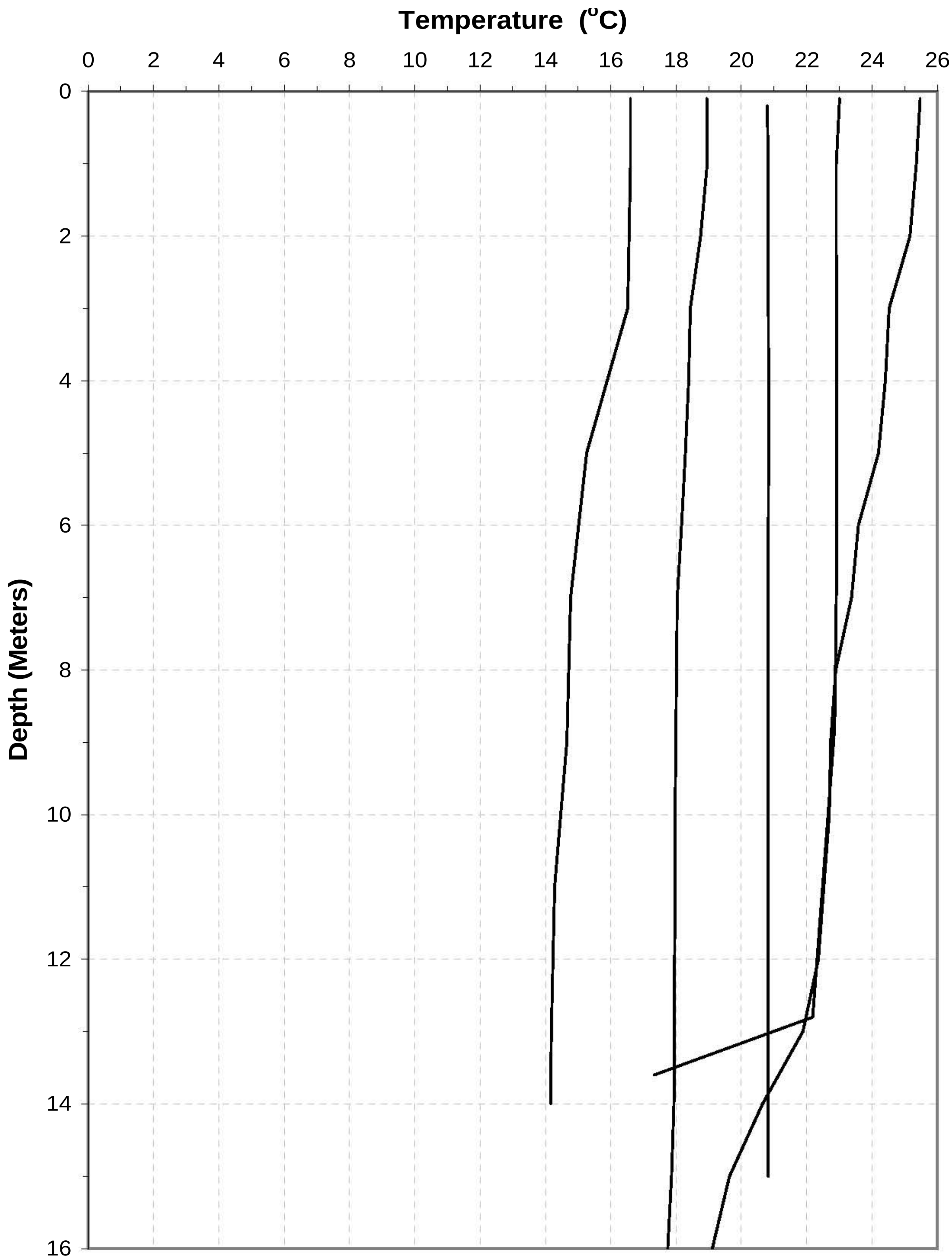


Plate 383. Temperature depth profiles for Lake Audubon generated from data collected at the near-dam, deepwater ambient monitoring site during the summer months of 2002 and 2006.

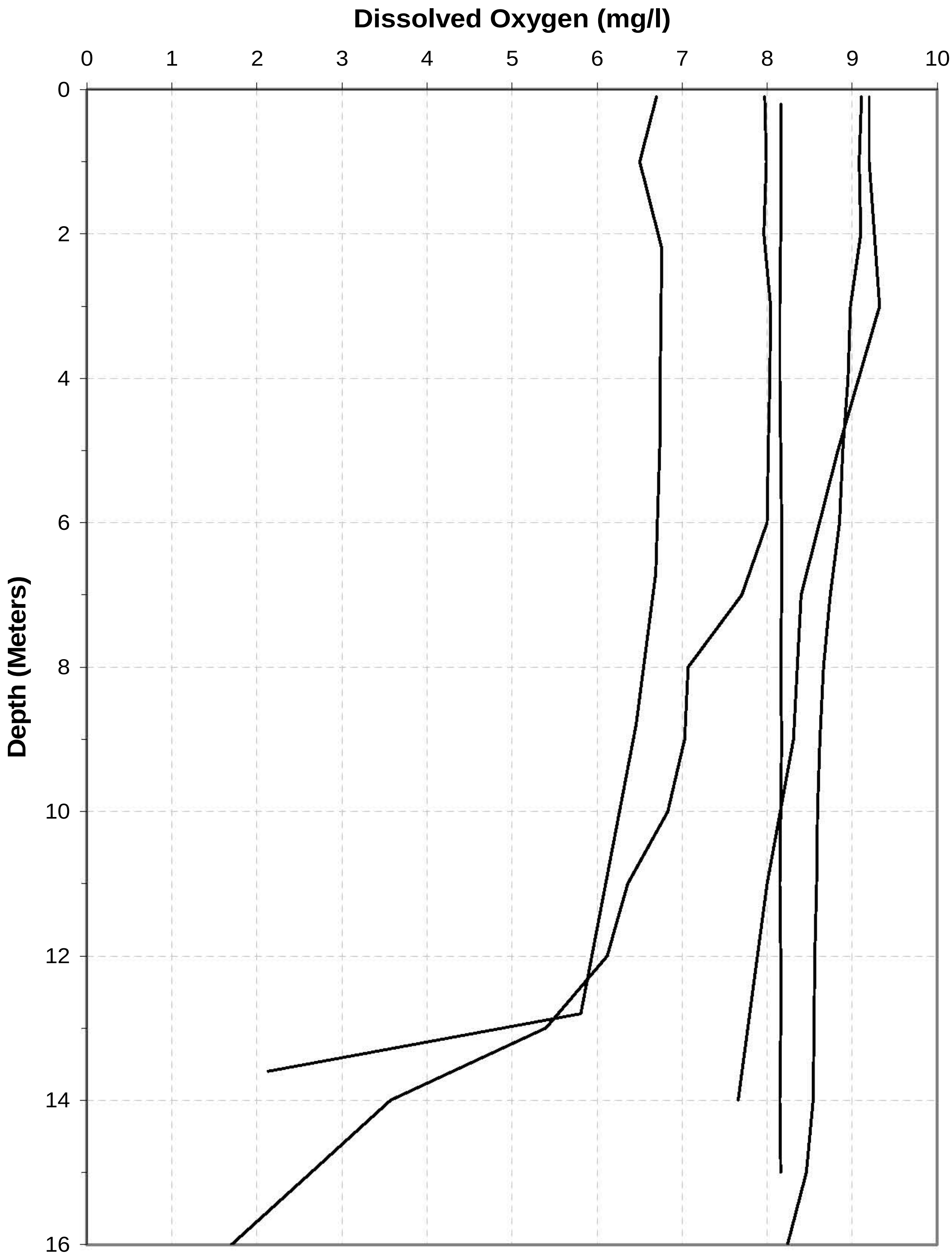


Plate 384. Dissolved oxygen depth profiles for Lake Audubon generated from data collected at the near-dam, deepwater ambient monitoring site during the summer months of 2002 and 2006.

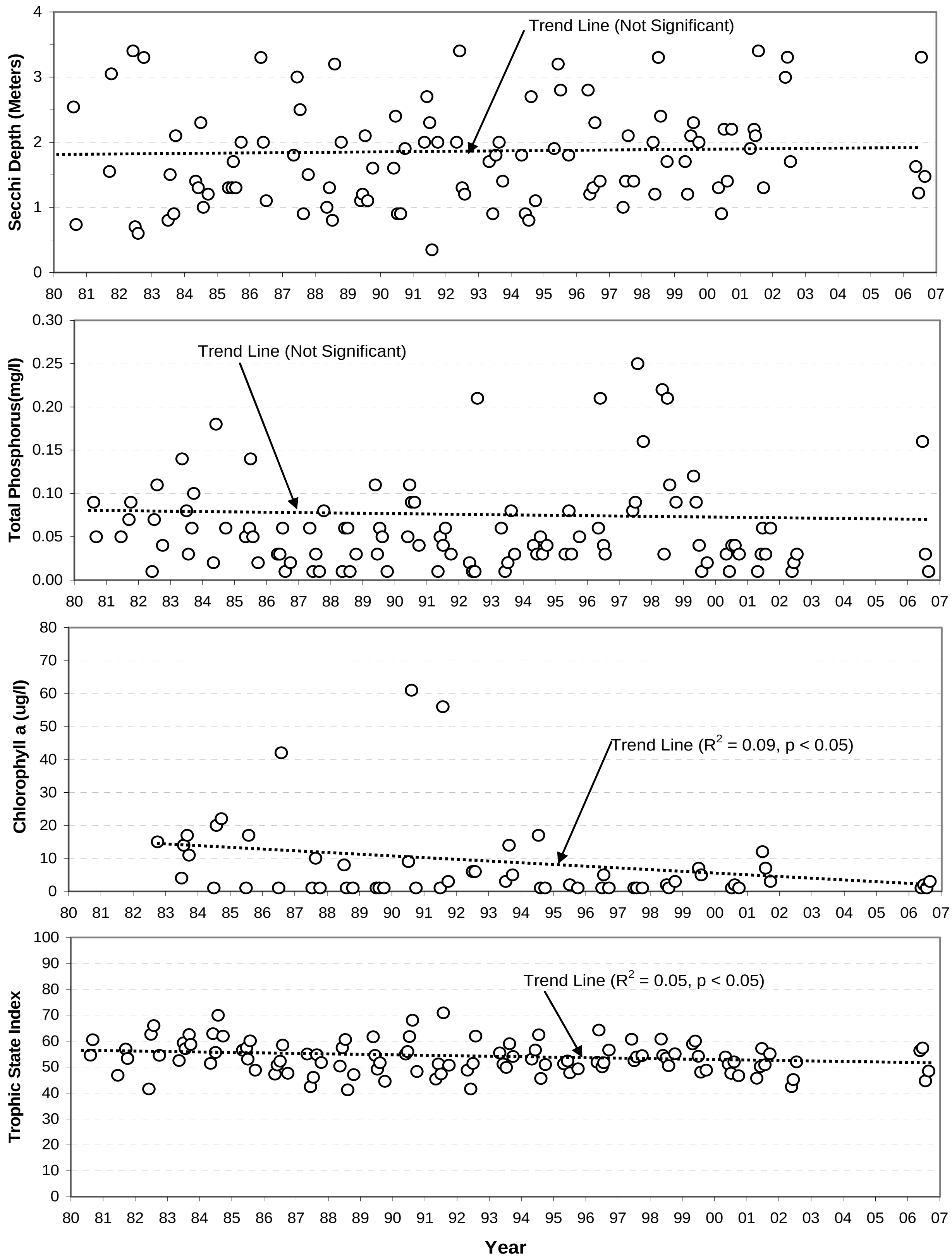


Plate 385. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and Trophic State Index (TSI) monitored in Lake Audubon at the near-dam, ambient site over the 27-year period of 1980 through 2006.

Plate 386. Summary of monthly (May through September) water quality conditions monitored in Lake Yankton (i.e., site YAKLKND1) during 2002 and 2006.

Parameter	Monitoring Results						Water Quality Standards Attainment		
	Detection Limit[A]	No. of Obs.	Mean[B]	Median	Min.	Max.	State WQS Criteria[C]	No. of WQS Exceedences	Percent WQS Exceedence
Pool Elevation	1	5	1167.5	1167.5	1167.2	1167.7	-----	-----	-----
Water Temperature (C)	0.1	78	19.6	19.1	13.9	26.6	27[1,2,6], 29[1,2,6]	0	0%
Dissolved Oxygen (mg/l)	0 1	78	5.6	7.1	0.2	10.3	5[1,2,7]	28	36%
Dissolved Oxygen (% Sat.)	0.1	78	64.4	85.1	2.0	127.3	-----	-----	-----
Specific Conductance (umho/cm)	1	78	1,044	1,064	874	1,136	2,000[4]	-----	-----
pH (S.U.)	0.1	78	7.8	7.8	7.0	8.7	6.5[1,3,7], 9.0[1,3,6], 9.5[5,6]	0	0%
Oxidation-Reduction Potential (mV)	1	35	336	341	31	443	-----	-----	-----
Secchi Depth (in)	1	15	39	36	12	72	-----	-----	-----
Alkalinity, Total (mg/l)	7	27	195	200	140	238	-----	-----	-----
Ammonia, Total (mg/l)	0.01	17	-----	0.10	n.d.	0.46	12.1[1,6,9], 2.4[1,8,9]	0	0%
Carbon, Total Organic (mg/l)	0.05	21	3.4	3.3	2.4	5.3	-----	-----	-----
Chlorophyll *a* (ug/l) - Lab Determined	1	13	-----	4	n.d.	68	-----	-----	-----
Dissolved Solids, Total (mg/l)	5	10	714	705	680	790	-----	-----	-----
Hardness, Total (mg/l)	0.4	10	444	449	414	485	-----	-----	-----
Iron, Dissolved (ug/l)	40	10	-----	n.d.	n.d.	50	-----	-----	-----
Iron, Total (ug/l)	40	10	140	131	60	238	-----	-----	-----
Kjeldahl N, Total (mg/l)	0.1	27	-----	0.3	n.d.	1.0	-----	-----	-----
Manganese, Dissolved (ug/l)	2	10	1,407	285	7	6,620	-----	-----	-----
Manganese, Total (ug/l)	2	10	1,628	497	207	6,808	-----	-----	-----
Nitrate-Nitrite N, Total (mg/l)	0.02	27	-----	n.d.	n.d.	0.06	10[3,6], 100[4,6]	0	0%
Phosphorus, Dissolved (mg/l)	0.01	10	-----	n.d.	n.d.	0.02	-----	-----	-----
Phosphorus, Total (mg/l)	0.01	27	0.05	0.03	n.d.	0.22	-----	-----	-----
Phosphorus-Ortho, Dissolved (mg/l)	0.01	27	-----	n.d.	n.d.	0.15	-----	-----	-----
Sulfate (mg/l)	1	8	395	400	340	420	-----	0	0%
Suspended Solids, Total (mg/l)	4	27	-----	6	n.d.	17	158[1,6], 90[1,8]	0	0%
Antimony, Dissolved (ug/l)	0 5	4	-----	n.d.	n.d.	n.d.	88[10], 30[11], 6[12]	0	0%
Arsenic, Dissolved (ug/l)	1	4	-----	n.d.	n.d.	3.	340[10], 16.7[11], 10[12]	0	0%
Beryllium, Dissolved (ug/l)	2	4	-----	n.d.	n.d.	n.d.	130[10], 5.3[11], 4[12]	0	0%
Cadmium, Dissolved (ug/l)	0.2	4	-----	n.d.	n.d.	n.d.	25.4[10], 0.7[11], 5[12]	0	0%
Chromium, Dissolved (ug/l)	10	4	-----	n.d.	n.d.	n.d.	2,026[10], 263[11], 100[12]	0	0%
Copper, Dissolved (ug/l)	2	4	-----	n.d.	n.d.	n.d.	55.3[10], 32.3[11], 1,000[12]	0	0%
Lead, Dissolved (ug/l)	0.5	4	-----	n.d.	n.d.	n.d.	316[10], 12.3[11], 15[12]	0	0%
Nickel, Dissolved (ug/l)	10	4	-----	n.d.	n.d.	n.d.	1,668[10], 185[11], 100[12]	0	0%
Selenium, Total (ug/l)	1	4	-----	n.d.	n.d.	n.d.	20[4,10], 5[11], 50[12]	0	0%
Silver, Dissolved (ug/l)	1	4	-----	n.d.	n.d.	n.d.	45.7[10], 100[12]	0	0%
Zinc, Dissolved (ug/l)	10	3	-----	n.d.	n.d.	n.d.	422[10,11], 5,000[12]	0	0%
Microcystin	0 2	5	-----	n.d.	n.d.	n.d.	-----	-----	-----
Alachlor, Total (ug/l)[D]	0.05	7	-----	n.d.	n.d.	0.06	760[10], 76[11]	0	0%
Atrazine, Total (ug/l)[D]	0.05	7	-----	0.07	n.d.	1.07	330[10], 12[11]	0	0%
Metolachlor, Total (ug/l)[D]	0.05	7	-----	n.d.	n.d.	0.06	390[10], 100[11]	0	0%
Pesticide Scan (ug/l)[E]	0.05	2					-----	-----	-----
Atrazine, Total (ug/l)		2	-----	14.8	n.d.	29.6	330[10], 12[11]	1	50%
Chlorpyrifos, Total (ug/l)		2	-----	7.35	n.d.	14.7	0.083[10], 0.041[11]	1	50%

n.d. = Not detected.

[A] Detection limits given for the parameters Stream Flow, Water Temperature, Dissolved Oxygen (mg/l and % Sat.), pH, Specific Conductance, and Oxidation-Reduction Potential are resolution limits for field measured parameters.

[B] Nondetect values set to 0 to calculate mean. If 20% or more of observations were n.d , mean is not reported. The mean value reported for pH is an arithmetic mean (i.e., log conversion of logarithmic pH values was not done to calculate mean).

[C] Criteria given for reference – actual criteria should be verified in appropriate State water quality standards.

- [1] Criteria for the protection of Warmwater Permanent Fish Life Propagation Waters (South Dakota) or Class I Warmwater Aquatic Life (Nebraska).
- [2] South Dakota's temperature criterion is 27 C and Nebraska's is 29 C. South Dakota's dissolved oxygen criterion is 6 mg/l and Nebraska's is 5 mg/l.
- [3] Criteria for the protection of domestic water supply waters.
- [4] Criteria for the protection of agricultural water supply waters.
- [5] Criteria for the protection of commerce and industry waters.
- [6] Daily maximum criterion (monitoring results directly comparable to criterion).
- [7] Daily minimum criterion (monitoring results directly comparable to criterion).
- [8] 30-day average criterion (monitoring results not directly comparable to criterion).
- [9] Total ammonia criteria pH and temperature dependent. Criteria listed are for the median pH and temperature conditions.
- [10] Acute (CMC) criterion for the protection of freshwater aquatic life.
- [11] Chronic (CCC) criterion for the protection of freshwater aquatic life.
- [12] Criterion for the protection of human health.

Note: Some of South Dakota's and Nebraska's criteria for metals (i.e., cadmium, chromium, copper, lead, nickel, silver, and zinc) are based on hardness. Criteria shown for those metals were calculated using the median hardness value.

[D] Immunoassay analysis.

[E] The pesticide scan includes: acetochlor, alachlor, ametryn, atrazine, benfluralin, bromacil, butachlor, butylate, chlorpyrifos, cyanazine, cycloate, dimethenamid, diuron, EPTC, ethalfluralin, fonofos, hexazinone, isophenphos, isopropalin, metolachlor, metribuzin, molinate, oxadiazon, oxyfluorfen, pebulate, pendimethalin, phorate, profluralin, prometon, propachlor, propazine, simazine, terbufos, triallate, trifluralin, and vernolate. Individual pesticides were not detected unless listed under pesticide scan.

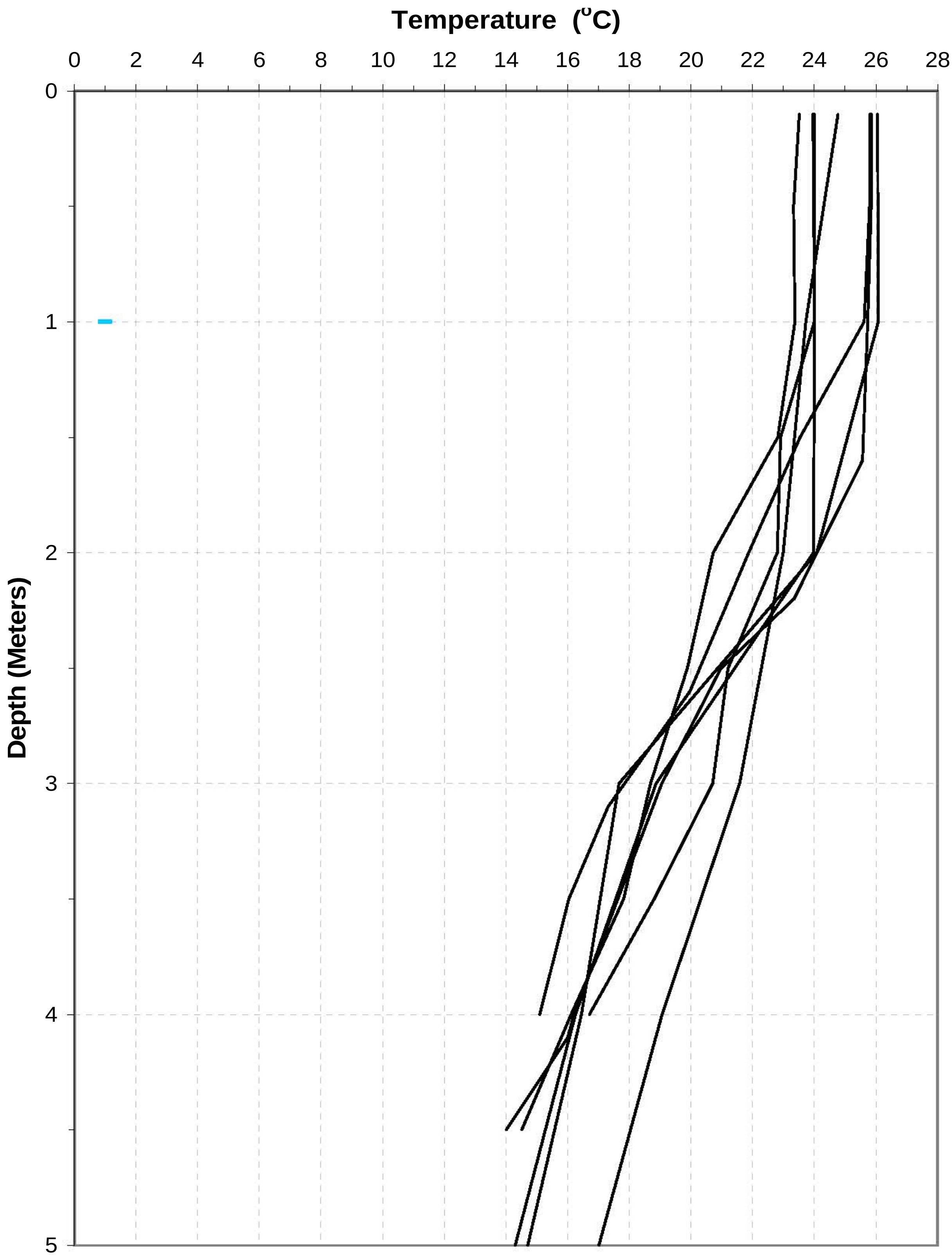


Plate 387. Temperature depth profiles for Lake Yankton generated from data collected at the deepwater ambient monitoring site during the summer months of 2002 and 2006.

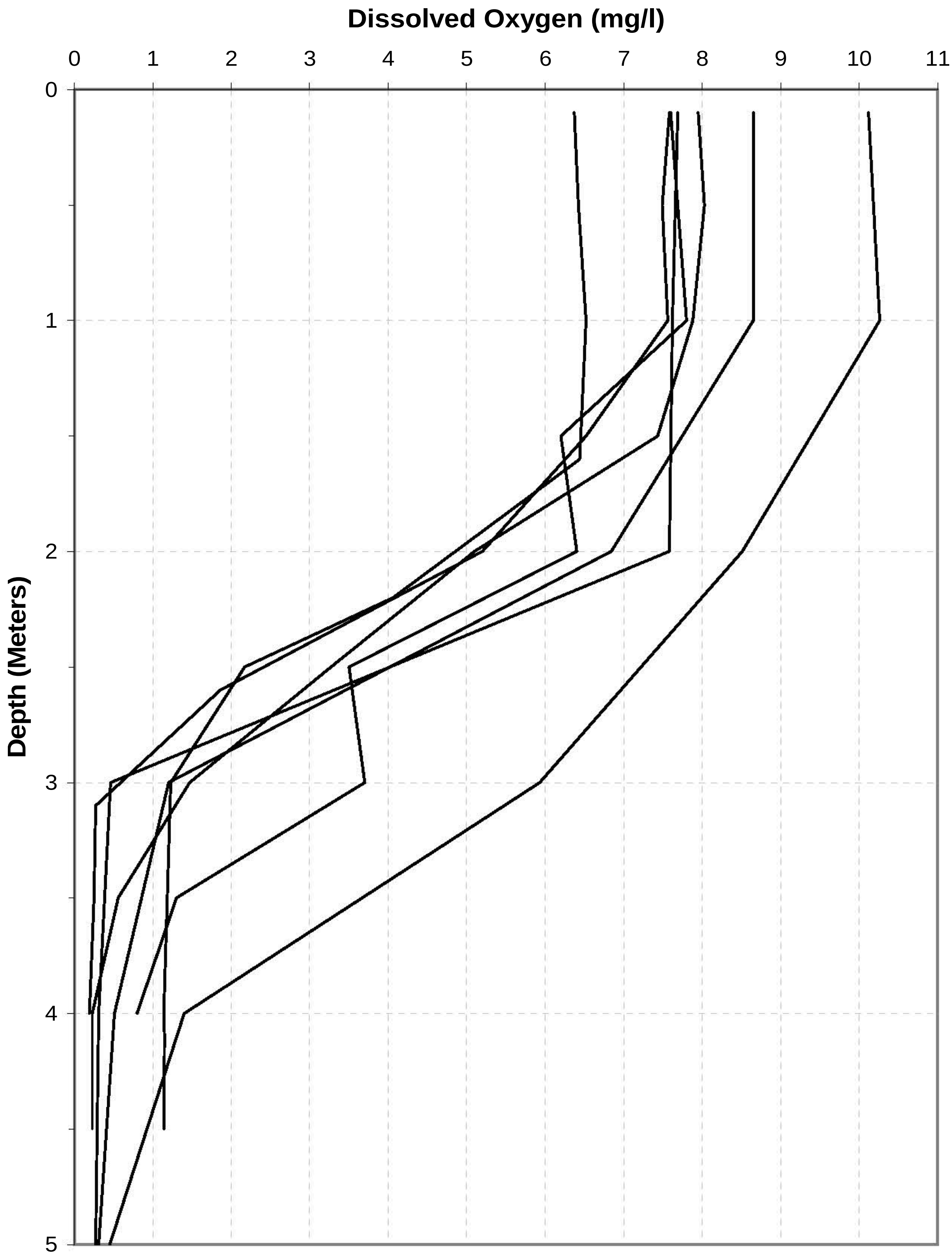


Plate 388. Dissolved oxygen depth profiles for Lake Yankton generated from data collected at the deepwater ambient monitoring site during the summer months of 2002 and 2006.

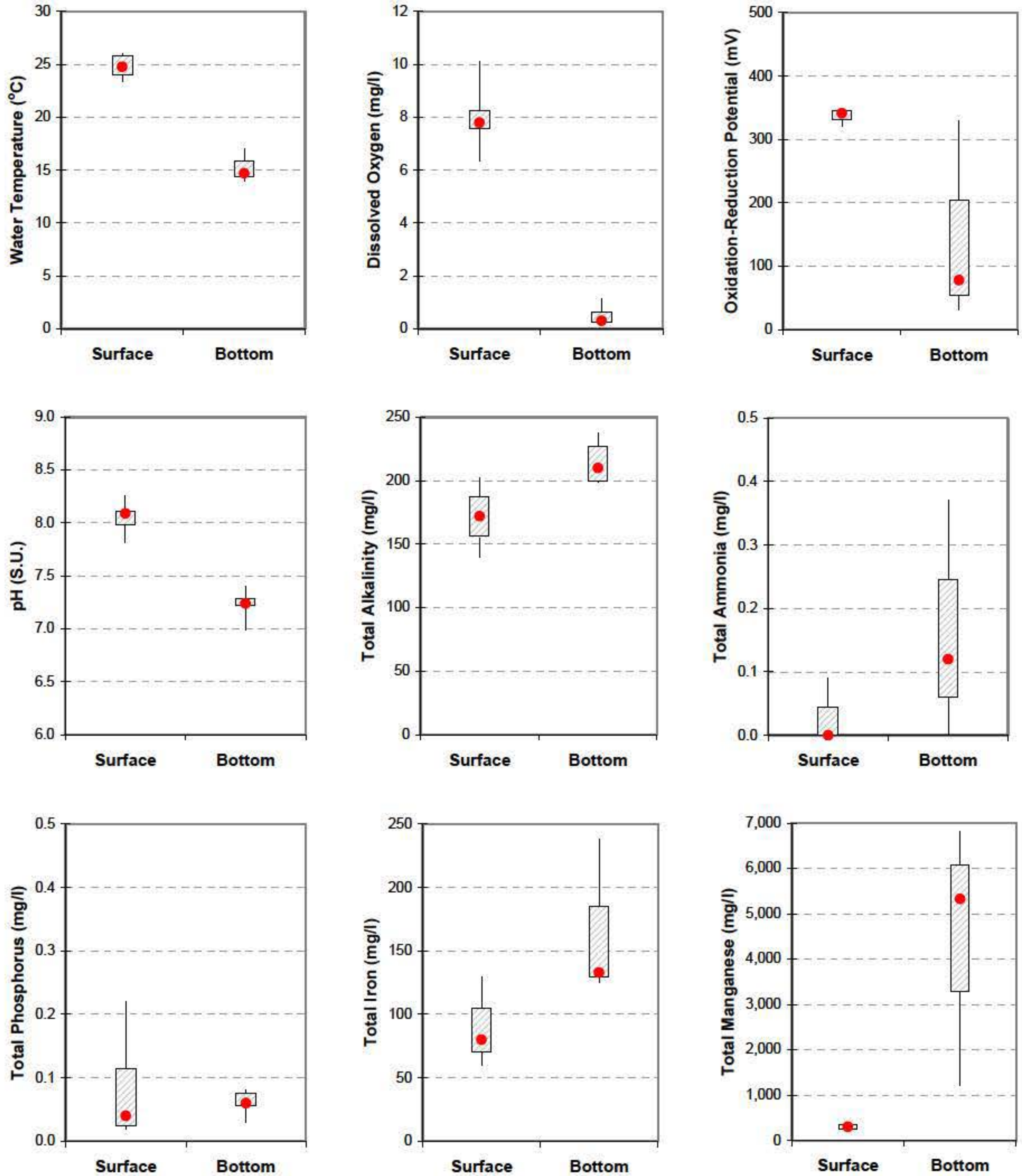


Plate 389. Box plots comparing surface and bottom water temperature, dissolved oxygen, oxidation-reduction potential, pH, alkalinity, total ammonia, total phosphorus, total iron, and total manganese measured in Lake Yankton at site YAKLKND1 during the summer months of 2002 and 2006.
(Box plots display minimum, 25th percentile, 75th percentile, and maximum. Median value is indicated by the red dot.)

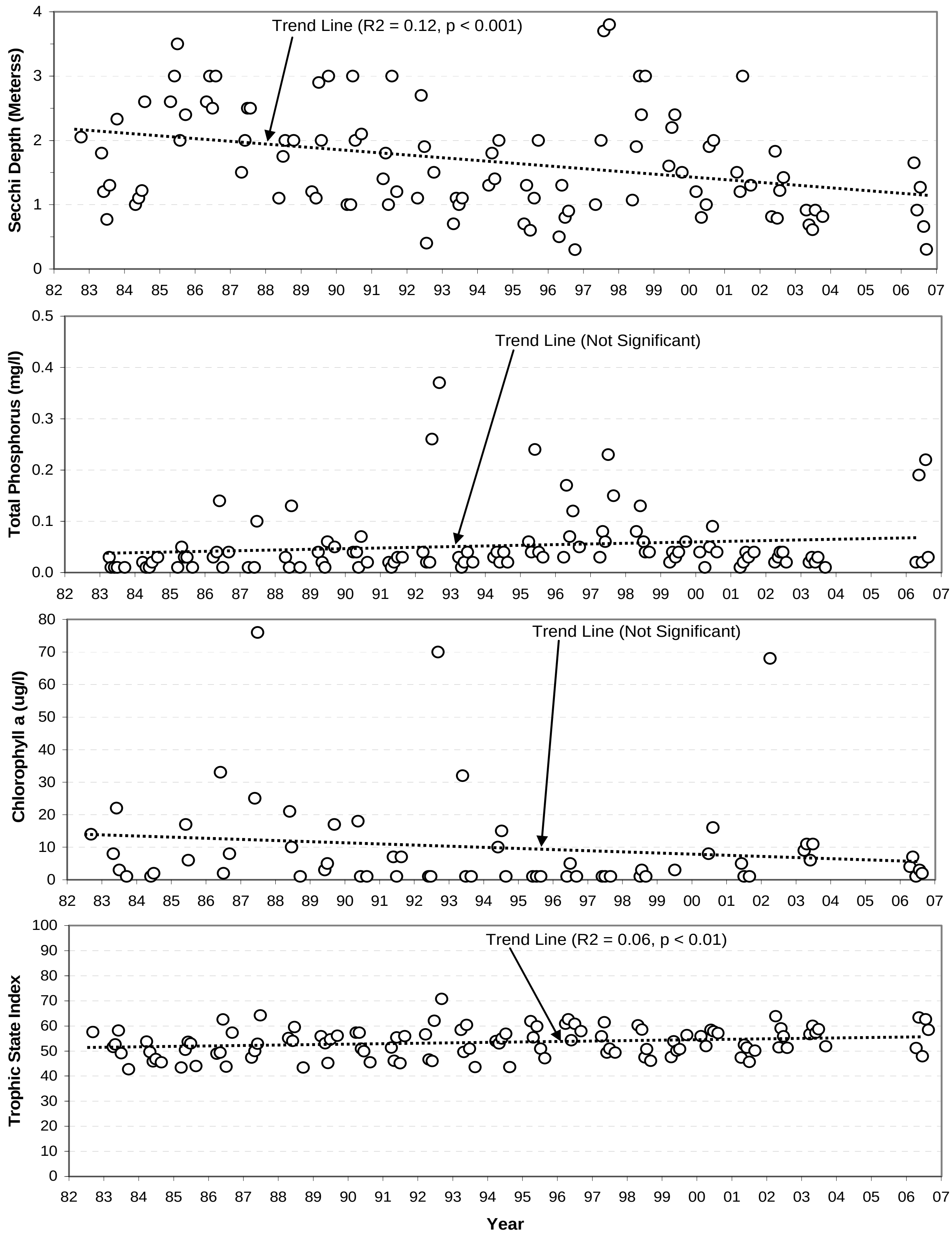


Plate 390. Historic trends for Secchi depth, total phosphorus, chlorophyll *a*, and Trophic State Index (TSI) monitored in Lake Audubon at the near-dam, ambient site over the 27-year period of 1980 through 2006.